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UNHOLTZ-DICKIE CORPORATION

vibration generation systems and measurement instruments

OPERATING INSTRUCTION MANUAL
MODEL D22PMBSLF, SN 605, 728

OPERATING AND SERVICING INSTRUCTIONS

MODEL D22PMB SERIES

BRIDGE CONDITIONING AMPLIFIER

MODEL D22PMB SLF

SERIAL NUMBERS 605, 728

SUMMARY

CIRCUIT SCHEMATICS A12502, A12503, A12504, A12505, B12547, C12501 A12410, A12506, A12507

SPECIAL FEATURES S, L, F

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1. GENERAL DESCRIPTION

The U-D Model D22PMB Bridge Conditioning Amplifier provides the necessary features of direct-coupled bridge conditioners plus a number of others that make the instrument easier to operate and more versatile than otherwise competitive instruments. The D22PMB is capable of operating with 1, 2, or 4 arm bridges, has provisions for internally completing the bridge, and contains a precision bridge power supply. Remote voltage sensing and single-shunt calibration check are standard features.

The instrument and associated bridge circuit is quickly and automatically balanced by momentarily pressing a front-panel switch. Calibration of the instrument is easily accomplished by dialing in the sensitivity of the bridge on the associated front panel controls. Calculation of the bridge sensitivity is simple because of the precision voltage supply.

The low-noise characteristics of the D22PMB are enhanced by selection of one of four signal pass bands. Maximum bandwidth is in excess of 50 kHz. Low drift, good zero stability, and good common mode rejection are provided. High common mode voltages (±300 V) are handled by a special circuit configuration which is described in a following section.

As a bridge conditioner, the D22PMB is well-suited for use with strain gages for the measurement of stress and strain, and with piezoresistive accelerometers for vibration measurements. A front panel switch also allows remote voltage or charge preamplifiers (U-D Models 11PA-2 or 22CA-2) to be used with the D22PMB. In this fashion, signals from capacitive transducers, such as piezoelectric accelerometers may be processed, thus increasing the versatility of the instrument.

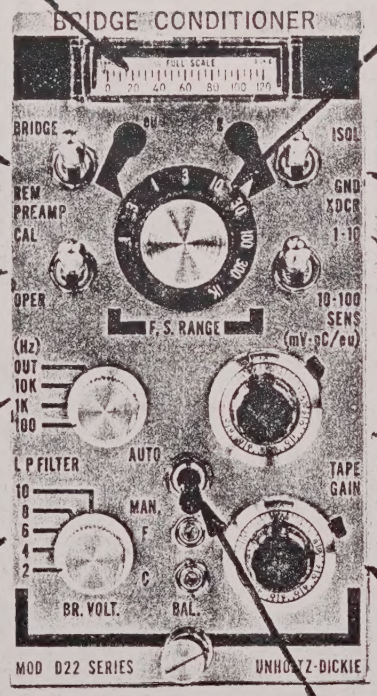
Integral Meter - reads peak AC value or $\pi/2$ times DC change

Select signal input from differential source (BRIDGE) or from remote preamplifier (REM)

Provides shunt calibration check for BRIDGE mode or oscillator input for REM mode

Select low-pass filter frequency (±3% response) to optimize S/N.

Bridge excitation voltage selected for maximum allowable gage dissipation



Set FULL SCALE RANGE directly in engineering units (1000 με, g, psi, etc). The LED indicators are controlled by the BRIDGE-REM switch.

Use GND Position for grounded transducers where mounting surface potential is as high as ±300 V.

Set bridge or transducer sensitivity. Automatically calibrates output in eu. For bridge:

$$S = \frac{A\ F\ V}{4} \quad \text{mV/1000 } \mu\varepsilon$$

Set desired full-scale output voltage on 10-turn dial

10 turns = ±10 V F.S.

Push up momentarily for fully automatic balancing - manual balancing in lower position.

2. CONTROLS-CONNECTORS

The front-panel controls are shown in Fig. 2.1, and the rear-panel outline in Fig. 2.2. All two-position toggle switches are locking and must be pulled out to switch to the other position.

2.1 Front Panel Controls (Fig. 2.1)

2.1.1 SENSITIVITY RANGE SWITCH (1-10), (10-100). This two position toggle switch establishes the range for the sensitivity of the bridge or accelerometer being used. The commonly used units for different applications are given in Table 2.1 below. The "engineering unit" (eu) for each application is specified.

eu	SENS UNIT	TRANSDUCER	MEASUREMENT
1,000 με	mV/1,000 με	Strain Gage(s)	Strain
10,000 psi	mV/10,000 psi	Strain Gage(s)	Stress
10g	mV/10g	Piezoresistive Accelerometer	Accel (0-1,000g)
100g	mV/100g	hi-g Piezoresistive Accelerometer	Accel (0-30,000g)
g	pC/g	Piezoelectric Accelerometers with Remote Charge Preamp	Accel

TABLE 2.1 UNITS FOR TRANSDUCER SENSITIVITY

2.1.2 SENSITIVITY DIAL. This ten-turn dial with locking brake and potentiometer is used to set the significant digits of the transducer sensitivity within the ranges indicated in 2.1.1. The dial can always be set between 1.0 and 10.0, and also somewhat above 10.0 and below 1.0, depending on the requirements of individual users (usually 0.5 to 10.5). The setting and reading accuracy is about 1% at 1.0 and 0.1% at 10.0 (one-half of one small scale division).

Strain Measurement

For strain gage bridges with all active arms having identical gages, the sensitivity, S, is determined by:

$$S = \frac{AFV}{4} \quad mV/1000\ \mu\varepsilon \qquad (2.1)$$

where A is the number of active arms (1, 2, or 4), F is the gage factor, and V is the bridge excitation voltage (see Section). For example for a two-active-arm bridge, gage factor of 2, and 10 V bridge excitation, we have:

$$S = \frac{2\ (2)(10)}{4} = 10\ mV/1000\ \mu\varepsilon \qquad (2.2)$$

This sensitivity could be set on either range, the 1-10 range being preferred because of lower noise.

Stress Measurement

Since stress = (Young's modulus)(strain), the relationship above can be modified slightly for a simple calculation of bridge stress sensitivity. If 10,000 psi is chosen as the engineering unit,

$$S = \frac{AFV}{4E} \times 10^7 \quad mV/10{,}000\ psi \qquad (2.3)$$

where E is Youngs Modulus in psi.

For example if the above gages were mounted on spring steel for which $E \approx 3 \times 10^7$ psi we have

$$S = 3.33\ mV/10{,}000\ psi \qquad (2.4)$$

Accelerometers

For piezoresistive accelerometers, the sensitivities are specified for the transducer with a given excitation voltage, usually 10 V DC. For accelerometers having upper limits from 200 to 1000 g the sensitivities are in the order of 1 mV/g. For these accelerometers, it is convenient to choose an "engineering unit" of 10 g and use a front panel setting of around 10 mV/10 g. The piezoresistive accelerometers having upper limits from 2500 to 30,000 g have sensitivities from .01 to .1 mV/g. It is convenient to choose an "engineering unit" of 100 g to provide front panel settings of 1 to 10 mV/100 g for these cases.

For piezoresistive accelerometers used with remote charge preamplifiers, use the charge sensitivity stated by the manufacturer and set it directly in pC/g. It is assumed that the charge preamplifier has a conversion ratio of 1 mV/pC.

2.1.3 MODE SWITCH - (BRIDGE - REMOTE PREAMP). This is a two position toggle switch which should be in the BRIDGE position for use with any bridge transducer (including piezoresistive accelerometers). In the REMOTE PREAMP position, signals are accepted from a remote voltage or charge preamp such as the U-D Model 22-CA-2. In the BRIDGE position the "eu" indicator lights, and in the REM. PREAMP position the "g" indicator lights. The frequency response in the REMOTE PREAMP mode is down less than 2% at 2 Hz and less than 5% at 1 Hz.

2.1.4 FULL-SCALE RANGE (eu or g). A rotary switch having the full scale range values engraved on the skirt of the knob. For manual ranging, the switch has five positions and the "eu" or "g" pilot light indicates which numerical value to read. The full scale values in "engineering units" are 0.1, .3, 1, 3 and 10 eu. For acceleration measurements with the remote preamp (g) the full scale values are 10, 30, 100, 300, and 1000 g. Peak values are used for sinusoidal measurements.

For example for strain-gage measurements with 1000 με = 1 eu, the full scale ranges are 100, 300, 1000, 3000 and 10,000 με.

For externally controlled ranging (Option E) or for automatic ranging (Option A) the switch positions are slightly different. See the special features.

2.1.5 TAPE GAIN. A ten-turn potentiometer with a turns-counting dial and locking brake, which varies the full-scale voltage at the OUT connector from 0 to 10 V peak. For example, a setting of 5.00 turns yields an output of 5.00 V peak for an input value equal to the setting of the F.S. RANGE switch. Full CW (10 turns) yields a full-scale output of 10 V peak.

2.1.6 LOW-PASS FILTER. A four-position switch allowing selection of four signal bandwidths. The frequency response characteristics and noise properties are summarized below for each switch position.

FILTER POSITION (HZ)	RESPONSE FREQ (Hz)			MAX NOISE (RTI)	
	±1%	±3%	-3 dB (TYP)	SENS RANGE	
				1 - 10	10 - 100
100	50	100	200	5 μV pp	20 μV pp
1K	500	1K	2K	1 μV rms	5 μV rms
10K	5K	10K	20K	2.5 μV rms	8 μV rms
OUT	10K	30K (±5%)	90K	6 μV rms	30 μV rms

TABLE 2.2: Frequency Response and Noise for Different Filter (Positions)

2.1.7 BRIDGE VOLTAGE. A five-position switch which allows selection of five highly-regulated, low-noise precision voltages: 2, 4, 6, 8, or 10 V for excitation of strain gage bridges. The power supply is rated at 100 mA, so that four-arm bridges having the following minimum resistances may be used on each voltage range.

VOLTAGE	2	4	6	8	10
MIN. ARM RESISTANCE (ohms)	20	40	60	80	100

2.1.8 BALANCE MODE (AUTO-BAL, AUTO-OPER, MAN.). A three-position toggle switch which is spring-loaded to return from the upper or AUTO-BAL position to the middle or AUTO-OPER position when finger pressure is released. The switch remains in the lower or MAN. position when placed there.

For fully automatic balancing of a bridge input, it is merely necessary to depress the switch upward momentarily until the meter returns to zero, and then release the switch arm. It is assumed that the bridge is mechanically unexcited for the balancing operation.

For manual balancing, push the switch downward to the MAN. position and adjust the coarse (C) and fine (F) balance potentiometers until balance is obtained on the meter or external monitor. Zero mechanical input is assumed. An input unbalance of ±10 mV may be compensated by either technique.

2.1.9 XDCR ISOL-GND. A two-position toggle switch for selecting the proper mode of operation when the transducer case or bridge reference is in electrical contact with the mounting surface. For situations in which the transducer case or bridge reference is electrically isolated from the mounting surface, use the ISOL position. However, if the transducer case or bridge reference is in electrical contact with the mounting surface, use the GND position.

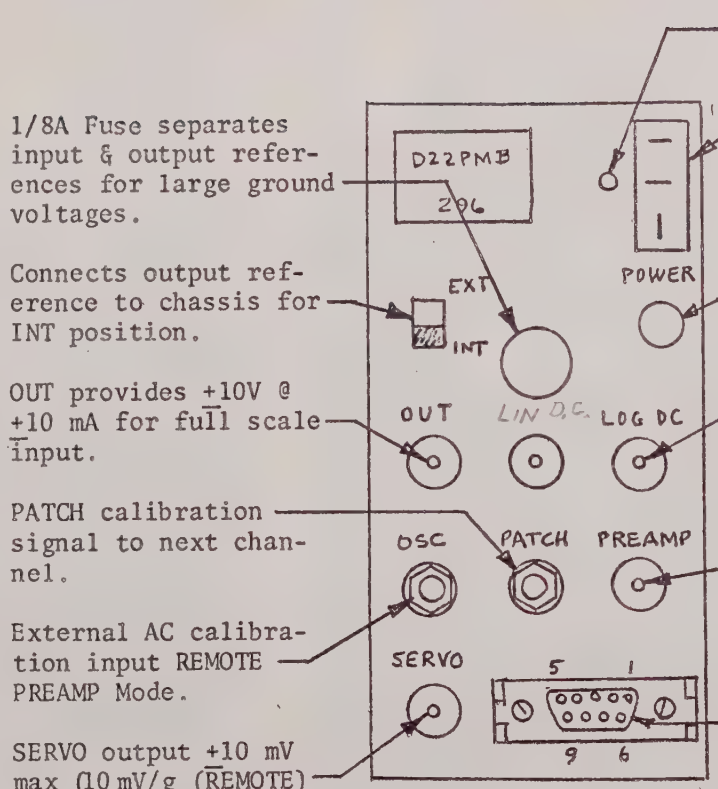
For situations in which the bridge is electrically isolated from the mounting surface, but where the mounting surface may be at rather high AC potentials relative to the instrument console ground (max ±300V), it is advantageous to use the GND mode to reject any capacitive feed to the input reference lead. The instrument will function in the GND mode even if the transducer is electrically isolated from the mounting surface.

2.1.10 CAL-OPER. A two-position toggle switch. In the CAL. position for the BRIDGE mode, a shunt calibration resistor is placed across a selected bridge arm to simulate a fixed strain. The resistor is selectable by the user and the arm across which the resistor is placed is determined by the wiring in the external cable connector. (See Sections 2.2, 3.1.2, and 3.1.3.)

In the CAL position for the REMOTE PREAMP mode, a sinusoidal calibration voltage may be inserted from the rear panel in place of the signal from the remote preamplifier. All range switches and other front panel controls are operative for these settings.

In the OPER position both calibration sources are disconnected.

2.1.11 METER. The meter responds to the average full-wave rectified value of the input and is calibrated in terms of the peak value of a sine wave. It responds to changes in DC value of the input but is not sign sensitive and the meter response is $\pi/2$ or 1.57 times the absolute value of the DC change.



1/8A Fuse separates input & output references for large ground voltages.

Connects output reference to chassis for INT position.

OUT provides +10V @ +10 mA for full scale input.

PATCH calibration signal to next channel.

External AC calibration input REMOTE PREAMP Mode.

SERVO output +10 mV max (10 mV/g (REMOTE) 1 V/eu (BRIDGE)

Power Cord Hold-Down

Power Connector

Power Fuse Buss GMW½

Log DC Output
0 V F.S. +1 V/decade

Input from Remote Preamp
(∿4 mA current supply)

Bridge Input Connector

PIN	FUNCTION
12 Violet 6	+Input
4 Gray 1	-Input
7 Yellow 3	– Input Ref & P.S. Return
Blue 4	+ Reg. Bridge P.S.
9 Orange 9	+P.S. Volt. Sens.
15 Black 8	Ref. P.S. Volt. Sens.
Green 2	Shunt Cal. Resistor
White 7	Shunt Cal. Resistor
Shell	Output Circuit Reference

FIG. 2.2 REAR PANEL
MODEL D22PMB

2.2 Rear Panel Features (Fig. 2.2)

2.2.1 BRIDGE INPUT CONNECTOR. An Amphenol DBC 9S connector with the shell insulated from the chassis and connected to output signal reference. The function of each pin is listed below:

PIN	FUNCTION
6	+ Input
1	- Input
3	Input reference and power supply return
4	Bridge regulated power supply
9	+ P.S. voltage sensing
8	- P.S. voltage sensing
2	Shunt calibration resistor
7	Shunt calibration resistor
SHELL	Output circuit reference

TABLE 2.3: Bridge Input Connector

The shield of the strain gage cable is normally connected to pin 3 (signal reference) and not to the shell of the connector. See Section 3.1 for typical input cable connections.

2.2.2 PREAMP. An isolated BNC connector for accepting a signal from a remote voltage preamplifier (Model 11PA-2) or remote charge preamplifier (Model 22CA-2) and providing the constant supply current necessary for its operation.

2.2.3 OUT. An isolated BNC connector which provides a peak output of ±10V for peak input value indicated on the F.S. RANGE switch, and for a full CW setting (10 turns) of the TAPE GAIN control. The current limit is ±10 mA.

2.2.4 OSC. A miniature phone jack for accepting an external sinusoidal calibration signal. The signal is active only for the CAL setting and the REM. PREAMP mode. If an internal oscillator (Option O) is located within the module, it is automatically disconnected when the external signal is plugged into the OSC jack.

2.2.5 PATCH. A miniature phone jack for patching the calibration signal to the next channel. The PATCH jack for channel #1 is connected to the OSC jack for channel #2, etc. The mating phone plug is Switchcraft TINI-PLUG #780 for both jacks.

2.2.6 SERVO (Option S). An insulated BNC connector which provides an output voltage of 10 mV/g in the REMOTE PREAMP mode. For the BRIDGE mode, the output sensitivity is 1V/eu. A maximum linear output of ±10 V peak is available.

2.2.7 EXT GND-INT GND. A two-position slide switch that connects the output circuit signal reference to the chassis in the INT GND position and leaves the signal ground floating in the EXT GND position.

If signal ground is common to the chassis in the external instrumentation, the EXT GND position may generally be used. However, if the third wire in the power cord is not carried to the power line ground, and the chassis is not electrically common to other chassis in the system, the INT. GND position should be used. The INT. GND. position should also be used if signal reference is not connected to chassis in the external instrumentation.

In a practical sense, the switch position should be used that shows a minimum amount of power frequency pickup with an oscilloscope monitoring the output(s) of interest.

2.2.8 POWER FUSE. Bussman GMW 1/2A in grey holder.

2.2.9 GND FUSE. Bussman AGC 1/8A in black holder. This fuse connects the input reference bus with the output reference bus. It automatically fails and puts the instrument in the GND XDCR mode when a large voltage exists between the input reference bus and the output reference bus.

2.2.10 POWER. A three-pin connector which mates with the 22RA rack adapter power strip or the individual line cord.

2.3 Chassis Screwdriver Adjustments

These potentiometer adjustments are made from access holes located on top of the chassis and are appropriately marked. Adjustment is generally made only during periodic calibration checks.

2.3.1 CAL. For instruments with the SERVO output, this trimmer is used to adjust the AC output calibration constant to 1 V/eu (or 10 mV/g). The adjustment is made before the METER and internal adjustment for full scale TAPE output are made.

For the basic instrument with no SERVO output the CAL adjustment is set so that the full-scale AC TAPE output is obtained for a calibration signal corresponding to the full-scale value indicated by the F.S. RANGE switch.

2.3.2 METER. The adjustment is made to provide full-scale meter deflection when an AC calibration voltage corresponding to the full-scale value indicated by the F.S. RANGE switch is applied to either the OSC input or one of the differential bridge inputs.

2.3.3 OSC (Option O). The adjustment is used to set the internal 100 Hz calibration oscillator to 100 mV peak. The internal oscillator can be monitored at the PATCH connector for this adjustment.

2.4 Internal Screwdriver Adjustments

These potentiometer adjustments can only be made by removing the top cover of the chassis. They have been carefully set at the factory and should only be readjusted if a malfunction is suspected. These adjustments are described for each printed circuit card.

2.4.1 DIFF AMP & AUTO CORRECTION DRIVER (12470)

GAIN - Used to adjust the AC gain of the differential amplifier to a value of 100 in the 1-10 SENS range.

BAL - Provides zero average output when BALANCE MODE switch is in AUTO BAL position. Hold switch in AUTO-BAL position and adjust for zero DC TAPE output with no input signal present. See 4.1.4.

2.4.2 BRIDGE POWER SUPPLY (12471)

BR. VOLT. - Used to calibrate power supply voltage. Monitor DC voltage between pins 4 and 3 of Bridge Input Connector with DC DVM, put BR. VOLT switch at 10 V, and adjust BR. VOLT for exactly 10.00 V DC.

2.4.3 DIAL-A-GAIN AMP. (12307)

BAL - Used to adjust DC output of the card to zero V DC when balance adjustment for the DIFF AMP (12470) has been properly made (see Section 4.1)

CAL - See 2.3.1

CURR - Used to adjust current source for remote preamplifier to approximately 4 mA. Compliance voltage at center pin of PREAMP connector should be 10 ±1 V DC.

2.4.4 DIFF. AMP - TAPE DRIVER (12311)

NULL - Used to adjust the output (OUT) of the instrument to a minimum when a test AC signal is inserted between the shell of the PREAMP connector and the shell of the TAPE output connector. The XDCR switch should be in GND position, the FS RANGE in 0.1 eu, SENS at 10 (1-10), MODE in BRIDGE position, and both bridge inputs grounded (6 and 1 to 3). In this way rejection of ground difference potentials is accomplished.

BAL - Used to adjust the DC voltage at the OUT connector to zero V DC when the previous balance adjustments have been properly made (see section 4.1).

GAIN - Used to adjust the TAPE output to 10 V AC pk for a TAPE GAIN setting of 10 turns and a calibration voltage equal to the full-scale value indicated by the F.S. RANGE switch. The adjustment is always made after the CAL adjustment (2.3.1) for the SERVO output is made.

2.4.5 SERVO-METER (12373)

BAL - Used to null the output of the first stage of the AC-DC converter (point A) for zero signal input.

ZERO - Used to null the output of the last stage of the AC-DC converter (point B) after the BAL adjustment has been made. These adjustments are critical only when wide range converter outputs are required, as with the LOG (Option L) output.

2.4.6 LOG DC (12401) (Option L)

0 dB, 30 dB, 60 dB - Used to adjust the full-scale output, -30 dB output, and -60 dB output of the LOG DC converter respectively. See Section 4.11.

3. OPERATION

All toggle switches must be pulled out to switch.

3.1 Bridge Connection

Bridges with one, two, or four active arms may be accommodated with up to eight wire connections to the bridge. The inactive arms of the bridge may be completed externally but there are provisions inside the D22PMB xhassis for internal completion resistors. Fig. 3.1 shows several suggestions for various bridge connections. Access to the internal bridge completion resistor locations is described in the following section.

3.1.1 MOUNTING BRIDGE COMPLETION RESISTOR -

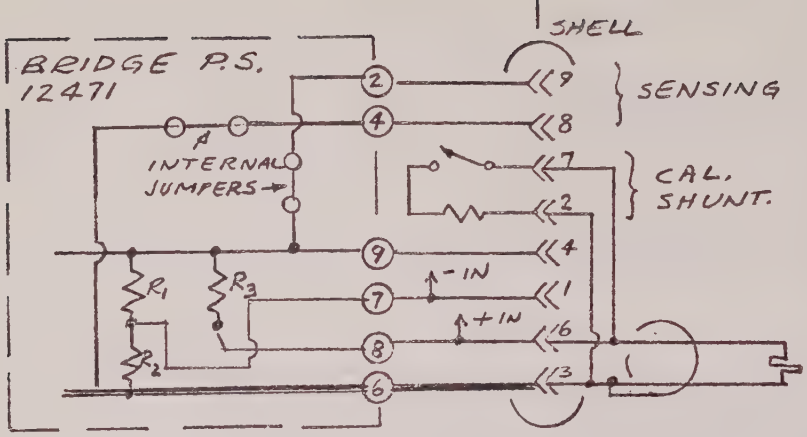
Remove the top and bottom covers of the instrument. From the underside of the chassis, remove the two screws holding the internal shields surrounding the DIFF-AMP, AUTO-CORRECTION DRIVER (12470) and BRIDGE POWER SUPPLY (12471) cards. The two cards are attached to the upper shield. Unplug the upper shield assembly and unscrew the two screws holding the BR. P.S. card (on side nearest the large holes). Do not lose sponge insulator covering the integrated circuit on the DIFF AMP card.

The bridge completion resistors may be soldered between the appropriate terminals on the BR. P.S. card. The resistor locations are numbered R1, R2, R3, R4, on the conductor side of the card and are also shown in Fig. 3.1. The bridge completion resistors should be exceptionally stable. We recommend VISHAY S104 or S105 (±1 ppm/^{o}C). Tolerance should be ±0.1% to allow less than 10 mV imbalance with a 10 V supply.

Assemble in the reverse order above, taking care to see that the insulating sponge covers the integrated circuit on the DIFF AMP card.

3.1.2 CHOICE OF BRIDGE NETWORK-

Fig. 3.1 does not show an exhaustive display of all combinations. For example, external voltage sensing could be used with two active arms. Note also that the single shunt calibration terminals (7 and 2) may be placed across other arms of the bridge, rather than across terminals 6 and 3.

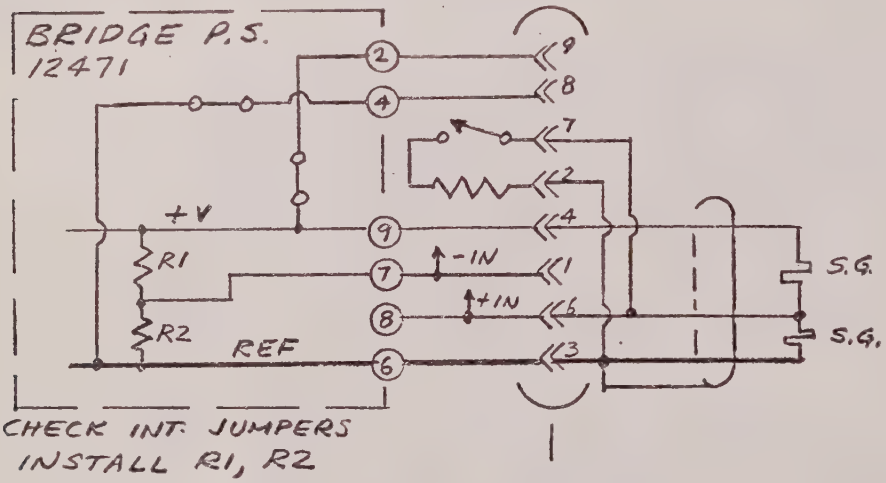


(a)

ONE ACTIVE ARM
INTERNAL SENS.
SINGLE SHUNT AT CONNECTOR
2 WIRES + SHIELD
OR
1 WIRE + SHIELD

CHECK INTERNAL JUMPERS
INSTALL R1, R2, R3

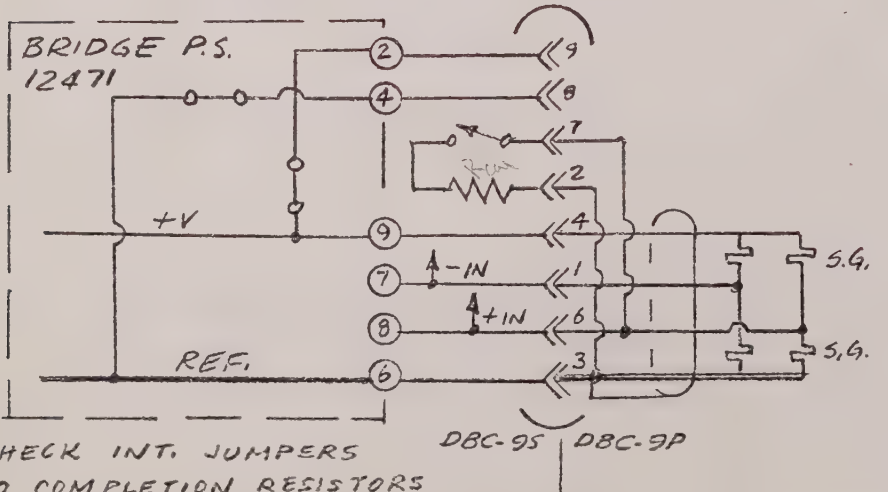
INSTALL JUMPERS IN CONNECTOR
DO NOT CONNECT SHIELD TO SHELL



(b)

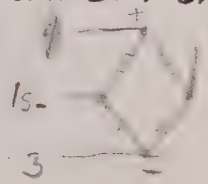
TWO ACTIVE ARMS
INTERNAL SENS.
SINGLE SHUNT AT CONNECTOR
3 WIRES + SHIELD
OR
2 WIRES + SHIELD

CHECK INT. JUMPERS
INSTALL R1, R2



(c)

FOUR ACTIVE ARMS
INTERNAL SENSING
SINGLE SHUNT AT CONNECTOR
4 WIRES + SHIELD.

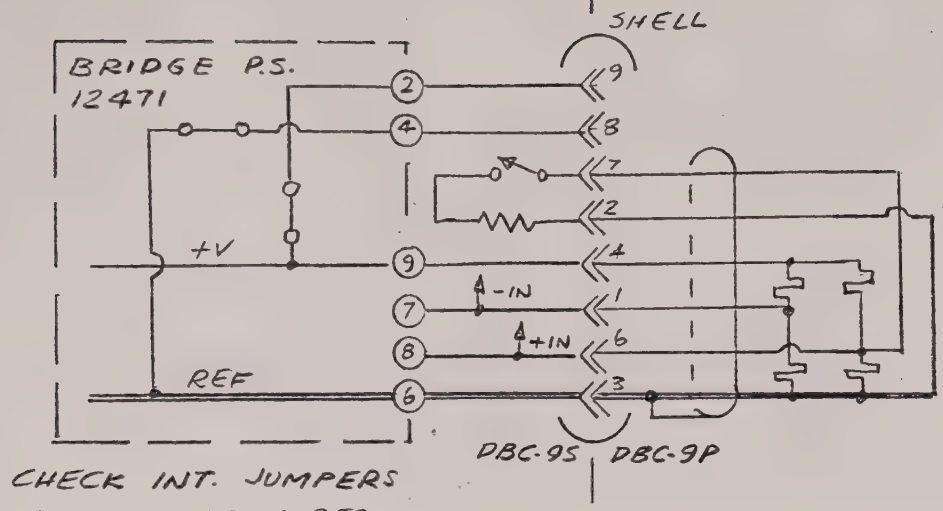


CHECK INT. JUMPERS
NO COMPLETION RESISTORS

DBC-9S | DBC-9P

FIG 3.1
BRIDGE CONNECTIONS

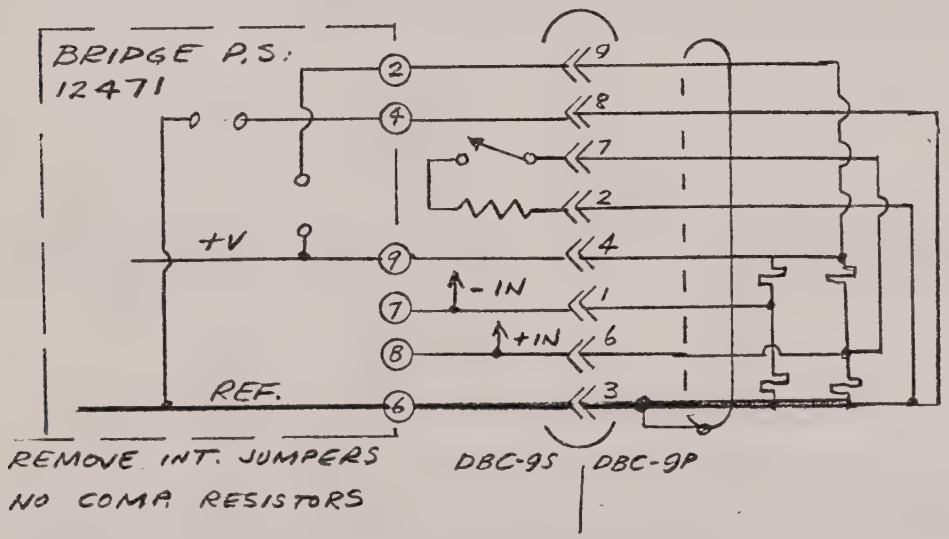
(d)



FOUR ACTIVE ARMS
INTERNAL SENSING
SINGLE SHUNT AT S.G
6 WIRES + SHIELD

CHECK INT. JUMPERS
NO COMPLETION RES.

(e)



FOUR ACTIVE ARMS
EXTERNAL SENSING
SINGLE SHUNT AT S.G
8 WIRES + SHIELD

REMOVE INT. JUMPERS
NO COMA RESISTORS

Simple strain measurements can be made with one, two, or four active arms. A one-active-arm bridge allows the use of simple coaxial cable but provides the poorest temperature stability since the completion resistor R3 and the gage are separated physically. The two-active arm bridge has good temperature stability, but more complicated wiring. The four-active arm bridge offers the greatest transducer stability. Derived strain measurements, such as shear strain, require a four-arm bridge. If the distance between the Model D22PMB and the measurement site is long, then external voltage sensing and single shunt calibration at the strain gage may be desired to eliminate long line resistivity effects on the bridge sensitivity and the calibration.

3.1.3 SELECTION OF SINGLE SHUNT CALIBRATION RESISTOR - The relation between relative resistance charge and strain is given by:

$$\frac{\Delta R}{R} = F\ (\text{strain}) = F \cdot \frac{\Delta L}{L} \qquad (3.1)$$

where F is gage factor and R is gage resistance. A shunt calibration resistor R_S across R causes a resistance change

$$\Delta R_{cal} = R - \frac{RR_S}{R + R_S} = \frac{R^2}{R + R_S} \simeq \frac{R^2}{R_S} \qquad (3.2)$$

It is assumed that $R_S >> R$. Since the ΔR due to actual strain occurs in all active arms of the bridge, the ΔR_{cal} in Eq. (3.2) must be A times greater than that in Eq. (3.1) to make the strain value equivalent (A = number of active bridge arms). Thus we have

$$(\text{Strain})_{cal} = \frac{1}{AF} \cdot \frac{R}{R_S} \qquad (3.3)$$

and the value of the single-shunt calibration resistor is

$$R_S = \frac{R}{AF\ (\text{strain})_{cal}} \qquad (3.4)$$

For example, if R = 120 Ω, F = 2.1, A = 1, and $(\text{strain})_{cal}$ = 1000 με, we have

$$R_S = \frac{120}{(1)(2.1)(10^{-3})} = 57.14 \text{ K ohm}$$

A 56.4 K ohm (±1%) resistor is factory-installed in the D22PMB to provide 1000 με calibration checks for a typical 120 ohm one-active-arm bridge. For two and four active arms, the calibration levels are 500 με and 250 με respectively.

3.1.4 EFFECT OF LONG LINES -
If the bridge excitation voltage is sensed internally, and not at the bridge, the voltage at the bridge is reduced by the IR drop in the connecting cable and the sensitivity as calculated by Eq (2.1) is inaccurate.

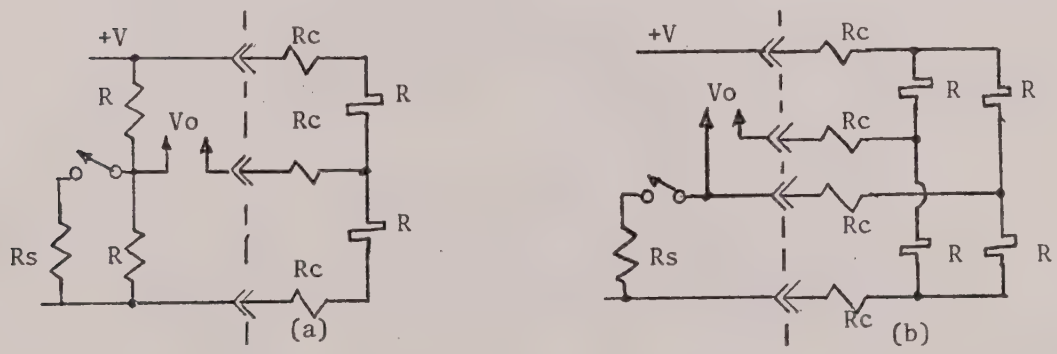


FIG. 3.2 CONFIGURATION OF BRIDGE WITH LONG LINES

For the two-active-arm bridge in Fig. 3.2(a) the sensitivity is:

$$S = \frac{FV}{2} \cdot \frac{R}{R_C + R} \qquad (3.5)$$

For the four-active-arm bridge in Fig. 3.2(a), the sensitivity is:

$$S = FV \cdot \frac{R}{2R_C + R} \approx FV \left\{1 - \frac{2R_C}{R}\right\} \qquad (3.6)$$

The resistance of #22 wire (7/30) is approximately 15 ohms/1000 ft. About 80 ft of cable is needed to cause a reduction of 1% in sensitivity for a two-active-arm bridge and about 40 ft of cable for a four-active-arm bridge with 120 ohm gages.

For the four-active-arm bridge with the shunt calibration resistor connected at the amplifier, as in Fig. 3.2(b) the simulated strain due to shunt resistor R_S is

$$(\text{Strain})_{cal} = \frac{1}{2F}\left\{\frac{2R_C + R}{5R_C + R + 2R_S} + \frac{R_C\,(2R_C + R)}{R(R_C + R_S)}\right\} \qquad (3.7)$$

Which reduces to:

$$(\text{Strain})_{cal} \simeq \left\{(\text{Strain})_{cal}\right\}_{R_C=0}\left\{1 + \frac{4R_C}{R}\right\} \qquad (3.8)$$

For the two-active-arm bridge as connected in Fig. 3.2(a) the simulated strain due to the shunt resistor is:

$$(\text{Strain})_{cal} \simeq \left\{(\text{Strain})_{cal}\right\}_{R_C=0}\left\{1 + \frac{R_C}{R}\right\} \qquad (3.9)$$

Neglecting line resistance in the calculation of R_S for a desired value of simulated strain causes the value of R_S to be smaller than necessary. Correction of R_S as calculated in (Eq. 3.4) by the factor $(1 + 4R_C/R)$ for the four-active-arm bridge and by the factor $(1 + R_C/R)$ for the two-active-arm bridge is adequate.

3.1.5 ACCESS TO SHUNT CALIBRATION RESISTOR-
Remove the top and bottom covers of the instrument. Then remove the bottom shield surrounding the connectors for the DIFF-AMP AUTO-CORRECTION DRIVER and BRIDGE P.S. cards. The shunt calibration resistor is located on two spring-loaded mounting terminals near the connectors. The resistor may be removed by depressing the tops of the spring loaded terminals. The value of the desired resistor may be calculated from Eq. (3.4) and new resistor inserted between the terminals.

3.1.6 CABLE AND CONNECTOR-
A wide variety of durable inexpensive shielded cable is available for connecting the strain gage to the D22PMB. Some suggestions are:

MFTR	TYPE	CONDUCTORS	O.D.	COMMENTS
Belden	8723	4(7/30)	.165	Shielded in pairs
Belden	8777	6(7/30)	.270	Shielded in pairs
Belden	8787	8(7/32)+2(7x30)	.256	2 unshielded 2 sets of 4 shielded
Alpha	2254/4	4(7/30)	.200	Spiral-wrap shield
Alpha	2254/6	6(7/30)	.235	Spiral-wrap shield
Alpha	6010	6(7/30)	.252	Mylar-foil shield
Alpha	6012	12(7/30)	.242	Mylar-foil shield

The matching connector for the rear-panel bridge input connector (see 2.2.1) is the amphenol DBC-9P. A special tool (ITT Cannon CCT-320D) is available for crimping conductors to the pins for the DBC-9P.

3.2 Piezoresistive Accelerometer

A piezoresistive accelerometer has either two or four active arms. For the accelerometer with two active arms, the completion resistors are usually internal. The bridge connections are specified by the manufacturer as is the accelerometer sensitivity.

3.3 Piezoelectric Accelerometer - Remote Preamplifier

For operation with a crystal or piezoelectric accelerometer, a remote charge preamplifier (Model 22CA-2) or a remote voltage preamplifier (Model 11PA-2) is required. Use a short length of low-noise subminiature microdot cable to connect the accelerometer to the preamplifier. The preamplifier output is connected to the PREAMP connector on the D22PMB by means of a standard RG/U coaxial cable of the necessary length and terminated with BNC connectors.

3.4 Specific Limitations on Input Voltages

The amplifier may be used as a general-purpose direct-coupled differential amplifier. However, the input voltages (between pins 6 and 3 and pins 1 and 3) must be limited to a maximum value of ±18 V to avoid damage. The voltage between the input reference (pin 6) and the output reference (shell of the OUT connector) may be as large as ±300 V, for the GND position of the GND-ISOL switch.

3.5 General Procedure

3.5.1 Connect the transducer of choice to the proper input. See Section 2.2.1, 2.2.2 and 3.1. Observe input precautions in 3.4, and choose proper setting of XDCR ISOL-GND (Section 2.1.9).

3.5.2 Make the proper front panel settings. Refer to Fig. 2.1 for thumbnail sketches of the control functions and to Section 2.1 for detailed descriptions.

3.5.3 Connect the OUT and SERVO outputs to the readout or control equipment as required. See Section 2.2.7 for recommendations for setting the EXT-INT GND Switch on the rear panel.

3.5.4 Apply line power by plugging in the instrument cord or by applying power to the Model 22RA Rack Adapter housing the instruments. Make certain that the proper F.S. RANGE indicator is ON.

3.5.5 Allow the bridge circuit at least 15 minutes to reach thermal equilibrium. Blanace the output either automatically or manually, as described in 2.1.8.

3.5.6 Monitor or record test data as required.

3.6 Calibration Check - BRIDGE Mode

3.6.1 Select a F.S. RANGE that is somewhat larger than the simulated level provided by the shunt calibration resistor. See 3.1.3 and 3.1.4.

3.6.2 Provide zero mechanical input and automatically balance the output.

3.6.3 Switch OPER-CAL to the CAL position and record the change of output voltage at the OUT connector. This should correspond to the correct value for the calibration level. For example if 1000 με is the calibration level, F.S. RANGE = 3000 με (3 eu), the output voltage change should be 3.33 V for a TAPE GAIN setting of ten turns. The METER deflection should be $\pi/2$ (.333) of full scale, or 52% of full scale.

3.6.4 If an oscillator signal is applied between either input pin (6 or 1) and input reference (pin 3) with the remaining pin connected to reference, the required output may be determined from the gain of the instrument in the BRIDGE mode:

$$GAIN = \frac{(\text{TAPE GAIN in turns})}{(\text{SENS. in mV/eu})(\text{F.S. RANGE in eu})} \times 10^3$$

For example the settings of TAPE GAIN full CW (ten turns), SENS = 1 mV/eu, and F.S. RANGE = .1 eu give the nominal maximum gain of 100,000 for the D22PMB. See 2.3.1 and 2.3.2 for necessary adjustments. Do not make readjustments on basis of measurements in 3.6.3. See Section 4.3.

3.7 Calibration Check - REM. PREAMP Mode

3.7.1 Set:

MODE	to	REMOTE PREAMP
OPER-CAL	to	CAL
SENS	to	10 mV/g
F.S. RANGE	to	10 g
TAPE GAIN	to	10 turns
LP FILTER	to	1 kHz
XDCR	to	ISOL

3.7.2 Apply 100 mV peak, 100 Hz, to OSC input.

3.7.3 Monitor the voltage at OUT with an ACVM and oscilloscope. No clipping should occur and the voltage should be 10.0 V peak ±1% (GAIN = 100) and the METER should read 100% of full scale.

3.7.4 For other conditions, the gain may be calculated from

$$GAIN = \frac{(\text{TAPE GAIN IN TURNS})}{(\text{SENS in mV/g})(\text{F.S. RANGE in g})} \times 10^3$$

3.7.5 Monitor the voltage at SERVO (S option only). It should be 100 mV/peak ±1% for the condition in 3.7.1.

3.7.6 See Sections 2.3.1, 2.3.2, 2.4.3, and 2.4.4 for gain adjustments.

3.8 Log DC Calibration (Option L)

3.8.1 The log DC output is usually used to plot output amplitude vs frequency as in Fig 3.3 on an X-Y recorder. With two Model D22 Series instruments ratios of two accelerations or of acceleration and force may be plotted.

3.8.2 Provide either log-log paper (2 x 3 or 3 x 5 are commonly used), or semilog paper (3 log x 70 linear) for recording.

3.8.3 On a range that will accommodate 1V/decade (20 dB), adjust the Y-ZERO control to locate pen at the top of the paper for direct amplitude recordings or near the middle for ratio recordings.

3.8.4 Provide the following connections and settings

LOG DC to (+) and (-) Y input
(-) Y input to GND Y input
} Amplitude Recordings

-or-

LOG DC (#1) to (+) and GND Y input
LOG DC (#2) to (-) and GND Y input
} Ratio Recordings

-and-

OPER-CAL to CAL
MODE Switch to REMOTE PREAMP
OSC input to 100 mV-peak (both channels)
SENS. to 10 mV/g
F.S. RANGE to 10 g

Allow at least five minutes warmup.

3.8.5 For amplitude recording adjust Y-ZERO control slightly for conditions above to align full-scale output with top division of paper.

3.8.6 Change F.S. RANGE to 100 g for one decade or -20 dB change. Adjust Y-GAIN for appropriate -20 dB or decade change on graph paper.

3.8.7 Repeat 3.8.5 and 3.8.6

3.8.8 For ratio recordings and alternate conditions in 3.8.4 adjust Y-ZERO control to align 0 dB on unity ratio point with a central paper division.

3.8.9 Change F.S. RANGE on channel #1 from 10 g to 100 g (-20 dB or -1 decade change). Adjust Y-GAIN for -20 dB change.

3.8.10 Change F.S. RANGE on channel #2 from 10 g to 100 g. Adjust Y-ZERO if necessary.

3.8.11 Change F.S. RANGE on channel #1 from 100 g to 10 g (+20 dB or +1 decade change). Readjust Y-GAIN for +20 dB change if necessary.

3.8.12 Change F.S. RANGE on channel #2 to 10 g and repeat 3.8.8 to 3.8.11

3.8.13 For additional dynamic range for ratio recording use the U-D Model MAC-8 or the Model ACS-6 with the Servo Control to let both plotted quantities vary in a controlled fashion rather than control one and let the other vary. In this fashion plotting range can be increased from 60 dB to 120 dB.

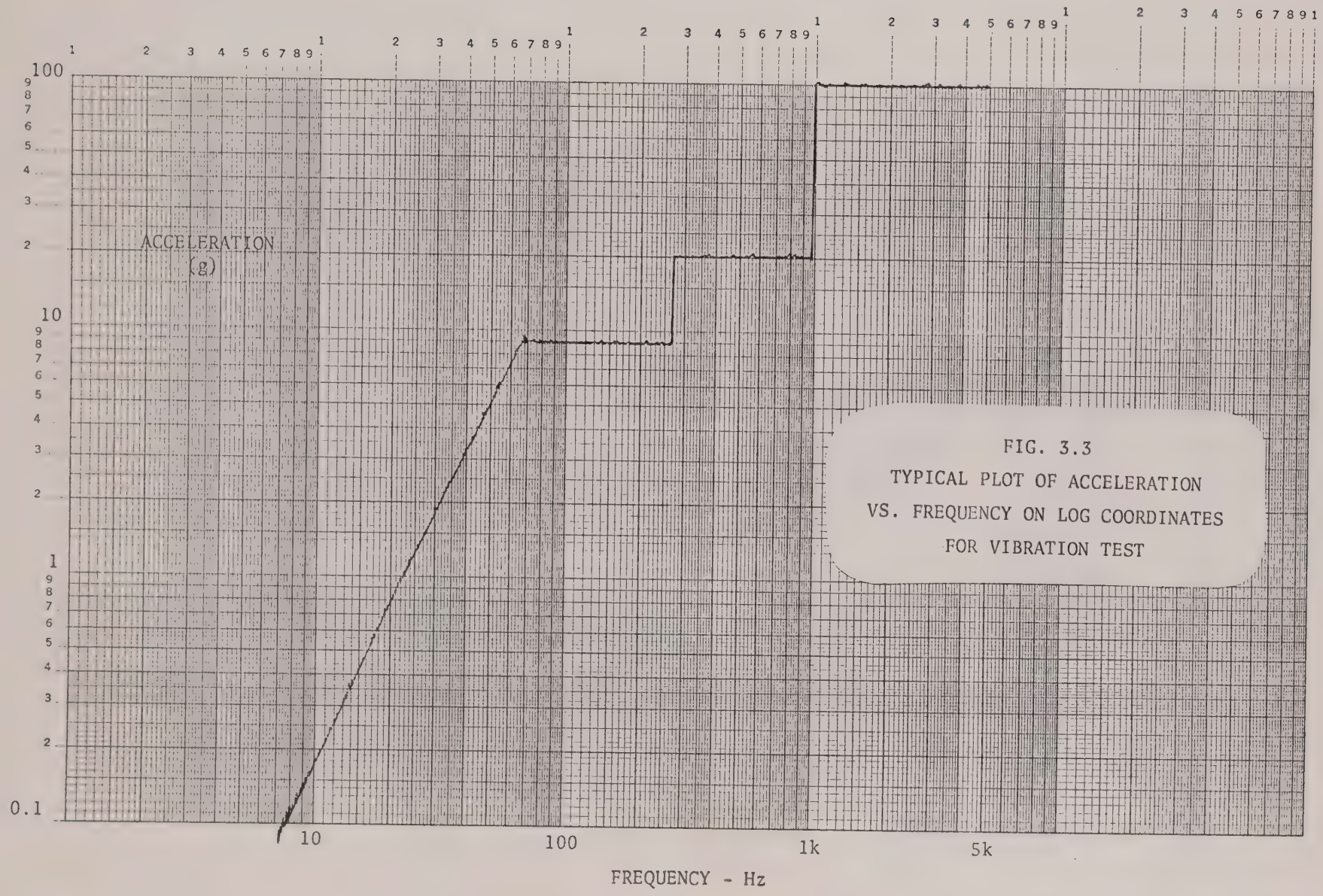


FIG. 3.3
TYPICAL PLOT OF ACCELERATION
VS. FREQUENCY ON LOG COORDINATES
FOR VIBRATION TEST

4. CALIBRATION CHECKOUT

Allow at least 15 minutes warm-up before attempting measurements.

4.1 Automatic Balance

4.1.1 Monitor the voltage at OUT with a direct-coupled oscilloscope. Provide an input connector so that pins 6 and 1 are shorted to 3, thus giving zero input. Check that there are no bridge completion resistors connected internally.

4.1.2 Instrument Settings:

MODE	to	BRIDGE
XDCR	to	ISOL
TAPE GAIN	to	10 V
L.P. FILTER	to	100 Hz
SENS	to	100
F.S. RANGE	to	1 eu

4.1.3 Hold the BALANCE MODE switch up in the AUTO-BAL position and wait until the OUTPUT reaches a final value. It should be 0 ±1 mV DC.

4.1.4 If the baseline voltage in 4.1.3 is out of tolerance, remove the top cover, and while holding the switch in the AUTO-BAL position, adjust BAL through the hole in the shield can on the DIFF AMP AUTO CORRECTION DRIVER (12470) card. (Section 2.4.1)

4.2 DC Balance

This section checks that the output null for zero signal input does not vary significantly with the setting of the F.S. RANGE or SENS potentiometer when the input amplifier is balanced properly.

4.2.1 Make the same arrangements as in 4.1.1.

4.2.2 Make the same settings as in 4.1.2 except that F.S. RANGE = .1 eu and SENS = 10 (10-100 range).

4.2.3 Null the output automatically (momentary AUTO-BAL position), and change the F.S. range switch to 10 eu. The output voltage should be 0 ±10 mV DC.

4.2.4 Change the SENS to 100 and F.S. to 0.1 eu. Null the output automatically and change the F.S. RANGE to 10 eu. The output voltage should be 0 ±10 mV DC.

4.2.5 The following adjustments are done only if the previous measurements in 4.2.3 and 4.2.4 are out of tolerance.

4.2.6 Remove the top and bottom covers of the D22PMB. Monitor the voltage at Pin 5 of DIFF-AMP, TAPE DRIVER (12311) card, and make the same arrangements as in 4.2.1.

4.2.7 Instrument settings:

MODE	to	BRIDGE
OPER-CAL	to	OPER.
XDCR	to	ISOL
TAPE GAIN	to	10 V
LP FILTER	to	100 Hz
SENS	to	10 (10-100 range)
F.S. RANGE	to	0.1 eu
BAL	to	MAN.

4.2.8 Adjust F and C for 0 VDC at the monitor. Change F.S. RANGE to 10 eu, and adjust BAL on DAG AMP (12307) card for 0 V DC. Return F.S. RANGE to 0.1 eu and repeat above procedure until null holds for both conditions.

4.2.9 With F.S. RANGE on 10 eu, vary SENS to 100. The monitored voltage should remain 0 ±10 mV DC.

4.2.10 Monitor voltage at the OUT connector with the oscilloscope. With F.S. RANGE = 10 eu, SENS = 100, adjust BAL on DIFF-AMP, TAPE DRIVER (12311) card for a null.

4.2.11 Repeat 4.2.1 through 4.2.4. These should be within tolerance. If not, consult factory.

4.3 Gain Calibration

4.3.1 INSTRUMENTATION

Connect the instrumentation as shown in Fig. 4.1. A precision step-attenuator, such as the Gertsch Ratio-Tran Model RT-7C or equal, is extremely valuable between the oscillator and D22PMB to facilitate range switch accuracy and gain checks. Always use an oscilloscope to monitor waveform purity, avoid ground loops between input and output circuits, and follow recommendations for INT-EXT GND switch in 2.2.7.

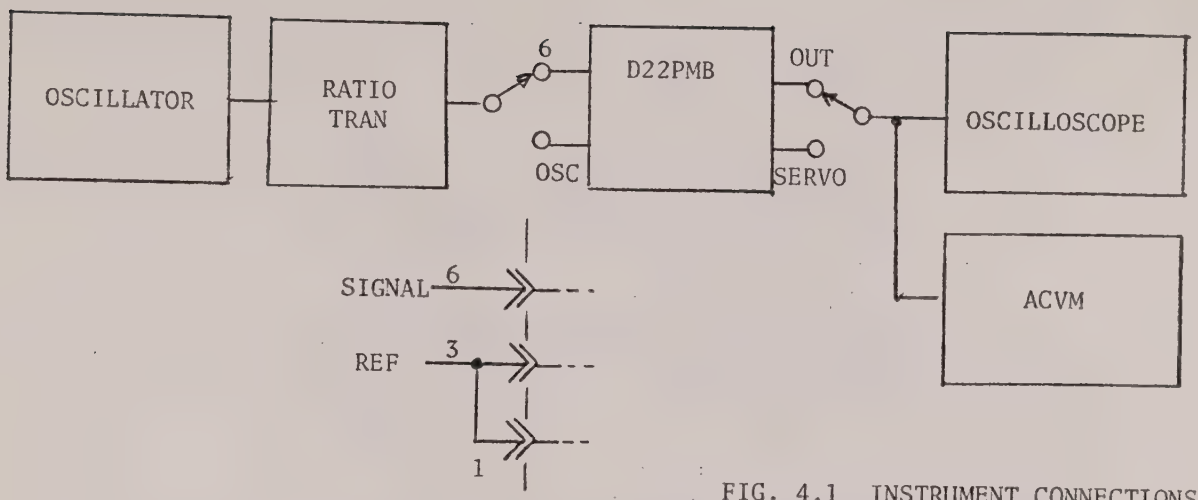


FIG. 4.1 INSTRUMENT CONNECTIONS

4.3.2 Instrument settings:

MODE	to	BRIDGE
OPER-CAL	to	OPER
XDCR	to	ISOL
TAPE GAIN	to	10 V
L.P. FILTER	to	1 kHz
SENS.	to	10 (1-10)
F.S. RANGE	to	10 eu

4.3.3 Apply 10.0 mV rms, 100 Hz, between input terminals 6 and 3 with terminal 1 grounded. Measure voltage at OUT. It should be 1.00 V rms ±1%.

4.3.4 Change SENS. to 100 with SENS. range switch. Voltage at OUT should be 100 mV rms ±1%.

4.3.5 Change MODE to REMOTE PREAMP, and OPER-CAL to CAL. Apply 1.00 V rms to OSC jack. The following outputs should be measured (F.S. RANGE = 1000 g) ±1%:

INPUT	SENS	OUT	SERVO
1.00 V rms	10 (1-10)	1.00 V rms	1.00 V rms
1.00	100 (10-100)	100 mV rms	100 mV rms

4.3.6 Should any of the above tests not be within the required tolerance, remove the top cover of the D22PMB and monitor the voltage at the inner arm of the MODE switch (in the BRIDGE position). This is the output of the INPUT DIFF AMP (12470) card. Apply voltage as in 4.3.3 or setting in 4.3.2.

4.3.7 Adjust GAIN through the hole of the inner shield on the INPUT DIFF AMP (12470) card for exactly 1.00 V rms output.

4.3.8 Change SENS range to 10-100. Output should be 100 mV rms ±1%.

4.3.9 Apply 1.00 V rms, 100 Hz, as in Section 4.3.5. Adjust CAL on DAG AMP card to obtain SERVO output of exactly 1.00 V rms for SENS. of 10 (1-10 range). Adjust GAIN on DIFF AMP-TAPE DRIVER (12311) card for exactly 1.00 V rms at OUT connector.

4.3.10 Change SENS to 100 by switching the SENS range switch. The voltage at the SERVO and OUT connectors should be 100 mV rms ±1%.

4.4 Sensitivity Dial Offset

This adjustment has been set carefully at the factory and should not need readjustment.

4.4.1 Instrument settings:

MODE	to	REMOTE PREAMP
OPER-CAL	to	CAL
XDCR	to	ISOL
TAPE GAIN	to	10 V
L.P. FILTER	to	1 kHz
SENS	to	100 (10-100)
F.S. RANGE	to	1000 g
1.00 V rms, 100 Hz	to	OSC jack

4.4.2 If necessary, adjust input voltage slightly to provide exactly 100 mV rms at the OUT connector.

4.4.3 Set SENS dial at 1.00 (1 turn). The voltage at OUT should be 1.00 V rms ±1%.

4.4.4 If the voltage in 4.4.3 is too high (low), turn SENS. dial CCW until stop is reached. Note the reading on the dial. Loosen the set screw on the knob and decrease (increase) the dial setting by one minor scale division for each 2% error in 4.4.3. Lock the setting, replace the dial and tighten the set screw, taking care not to move the shaft off the CCW stop. One adjustment is sufficient if the offset measurement is inaccurate by only a few percent.

4.5 Maximum Output

4.5.1 Instrument Settings:

MODE	to	BRIDGE
XDCR	to	ISOL
SENS.	to	10 mV/eu (1-10)
F.S. RANGE	to	10 eu
CAL-OPER	to	OPER
FILTER	to	1 kHz
TAPE GAIN	to	10

4.5.2 Balance the amplifier automatically, and apply 100 mV peak, 100 Hz, between terminals 6 and 3 with terminal 1 grounded.

4.5.3 The voltage at the OUT and SERVO connectors should be 10 V peak and should not show distortion or clipping at the peaks.

4.6 FULL SCALE RANGE Switch Accuracy

4.6.1 Instrument Settings:

MODE	to	REMOTE PREAMP
OPER-CAL	to	CAL
XDCR	to	ISOL
TAPE GAIN	to	10 V
L.P. FILTER	to	1 kHz
SENS.	to	10 (1-10 range)

Oscillator Signal, 100 Hz, to OSC jack

4.6.2 Adjust oscillator input according to the table below for associated F.S. RANGE settings. The precision ratio transformer is a helpful device for doing this while the oscillator voltage is constant at 1.00 V rms. The voltage at the OUT connector should be 1.00 V rms ±1% for all settings of F.S. RANGE.

OSCILLATOR (V rms)	F.S. RANGE
1.00	1000
.300	300
.100	100
.030	30
.010	10

4.7 Frequency Response (High-end)

4.7.1 Instrument Settings:

MODE	to	BRIDGE
XDCR	to	ISOL
SENS	to	100 mV/eu
F.S. RANGE	to	10 eu
TAPE GAIN	to	10

4.7.2 Balance the amplifier automatically, and apply 100 mV rms between terminals 6 and 3 with terminal 1 grounded. Adjust input slightly so that voltage at OUT connector is exactly 1.00 V rms at low frequencies (10 Hz).

4.7.3 The frequencies for given allowable percentage variations in the output voltage (OUT) as a function of the L.P. FILTER switch position are given in the table below.

RESPONSE VARIATION → / ↓ FILTER POSITION	±1%	±3%	(TYP.) -3dB
100	50	100	200
1k	500	1k	2k
10k	5k	10k	20k
OUT	10k	30k (±5%)	90k

Hz

4.8 Noise

4.8.1 Instrument Settings:

MODE	to	BRIDGE
XDCR	to	ISOL
F.S. RANGE	to	0.1 eu
TAPE GAIN	to	10

Short 6 and 1 to 3 (inputs shorted)

4.8.2 Balance the amplifier automatically and read the rms noise voltage with an ACVM. Read the peak-to-peak noise voltage with an oscilloscope, and make sure that power frequency hum is negligible.

4.8.3 The following table gives maximum noise readings at the OUT connector as different SENS settings and L.P. FILTER settings.

SENS → / FILTER POSITION ↓	10 (1-10 range)	100 (10-100 range)
100	50 mV p-p	20 mV p-p
1k	10 mV rms	5 mV rms
10k	25 mV rms	8 mV rms
OUT	60 mV rms	30 mV rms

4.9 Common Mode Rejection - Input Circuit

4.9.1 Instrument Settings:

MODE	to	BRIDGE
XDCR	to	ISOL
F.S. RANGE	to	0.1 eu
TAPE GAIN	to	10
SENS	to	10 (1-10 range)
L.P. FILTER	to	1k

4.9.2 Put a 1 kilohm metal film resistor in series with each input terminal (1 and 6). This must be done close to the input connector and may be done by inserting the resistor leads directly in the socket. See the sketch in Fig. 4.2.

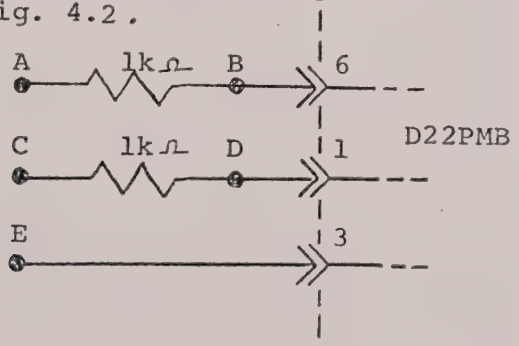


FIG. 4.2
INPUT CONNECTION

4.9.3 Make A and D common in Fig. 4.2 and apply 5V rms, 100 Hz, between A-D and E. Measure voltage at OUT connector.

4.9.4 Make B and C common and apply 5V rms, 100 Hz, between B-C and E. Measure voltage at OUT connector.

4.9.5 The measured output voltage in each case should be less than 0.5V rms (100 dB CMRR).

4.9.6 Change SENS to 100 (10-100 range) and repeat 4.9.3 and 4.9.4. The measured output voltage should be less than 0.25 V rms (86 dB CMRR).

4.10 Common Mode Rejection - Ground Circuit

4.10.1 Instrument Settings:

MODE	to	BRIDGE
XDCR	to	GND
F.S. RANGE	to	0.1 eu
TAPE GAIN	to	10
SENS	to	10 (1-10 range)
L.P. FILTER	to	1k

4.10.2 Short input terminals 6 and 1 to input reference (terminal 3). Apply the oscillator voltage between the shell of the OUT connector (OSC ref) and terminal 3 (OSC-high). Apply 5 V rms at 60 Hz.

4.10.3 Measure the voltage at the OUT connector. It should be less than 50 mV rms (120 dB). If not, change internal NULL adjustment as in Section 2.4.4.

4.11 Log DC Output (Option L)

4.11.1 Instrument Settings:

MODE	to	REMOTE PREAMP
OPER-CAL	to	CAL
XDCR	to	ISOL
L.P. FILTER	to	1k
TAPE GAIN	to	10V
SENS	to	10 mV/g
F.S. RANGE	to	1000 g

4.11.2 Monitor LOG DC output with a digital DC Voltmeter (DVM). Allow several minutes warmup. Apply voltage at 100 Hz to OSC input. The following table gives the output voltages corresponding to given input voltages.

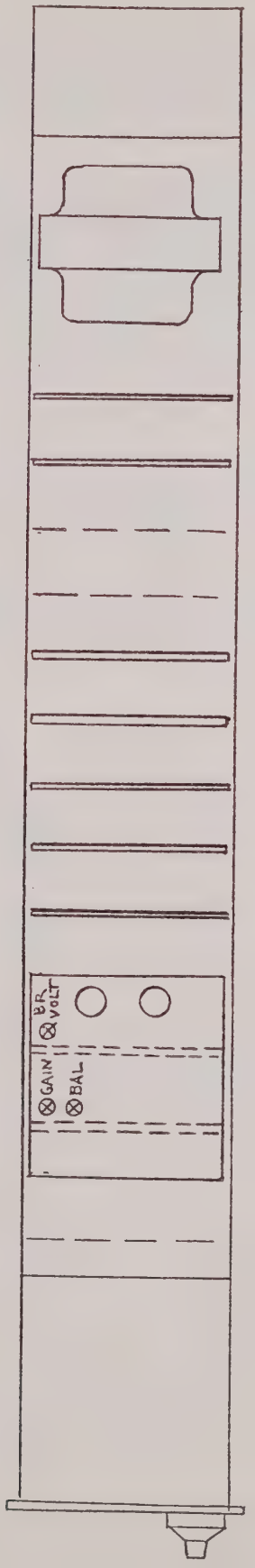
OSC	LOG DC	ADJUST
7.07 V rms	0 ±10 mV DC	0 dB
.224 V rms	-1.50 V ±10 mV DC	30 dB
7.07 mV rms	-3.00 V ±25 mV DC	60 dB

4.11.3 If any of the above LOG DC measurements exceed the tolerances given, remove the top cover and proceed as follows.

4.11.4 Monitor the input of the LOG DC board (pin 1) with the DVM. With zero OSC input, check the BAL and ZERO adjustments on the SERVO-METER card (12373) as noted in 2.4.5. A null less than 1 mV DC should be obtained.

4.11.5 Reconnect the DVM to monitor LOG DC output. For the input voltages to the OSC jack given in the table in 4.11.2 sequentially adjust the 0 dB, 30 dB, and 60 dB trimmers on the LOG DC card 12401 and repeat the adjustments if necessary to obtain the listed LOG DC outputs.

FIG. 5.1 CHASSIS LAYOUT



MODEL D22PMB

5. MAINTENANCE-SERVICING

5.1 Circuit Schematic

As an aid to understanding the operation of the Model D22PMB, refer to the circuit schematic in Dwg. No. C12501. The signal flow should be easily seen.

5.2 Chassis Layout

The layout of the chassis is shown in Fig. 5.1. The view is from the top with the top cover removed.

5.3 Access for Servicing

Although most normal calibration and checking procedures may be accomplished from the outside, as noted in Section 4, it may occasionally be necessary to inspect the printed circuit cards or connector wiring.

The top cover may be taken off by first removing three screws on the top of the chassis at the front and rear. The cover may be pulled up and off. To replace, slide the top cover in the groove formed by the bottom cover and the card tray and replace the screws. The removal of the top cover gives access to all printed circuit cards, except the INPUT DIFF AMP (12470) and the BRIDGE POWER SUPPLY (12471). These cards are enclosed in a separate isolated shield.

5.4 Input Cards

If access to either of the two input cards (12470 or 12471) is desired follow instructions in 3.1.1. Both shields are common to the input signal reference and are isolated from both chassis and output reference by approximately 300 kilohms when the ISOL-GND switch is in the GND position. The shield not only provides electrostatic shielding, but also provides mechanical rigidity and a thermal shield to reduce the effects of external air currents and sudden ambient temperature changes.

5.5 Voltage Measurements

Most significant voltage measurements are given in Section 4. However, if trouble is suspected, measurements of the regulated power supply voltages are often helpful.

CARD	TERMINALS	VOLTAGE
OUTPUT P.S.	1-2	20. ±4. V AC rms
OUTPUT P.S.	1-3	20. ±4. V AC rms
OUTPUT P.S.	10-6 REF	14.5 ± .5 V DC
OUTPUT P.S.	9-6 REF	14.5 ± .5 V DC
INPUT P.S.	1-2	25. ±4. V AC rms
INPUT P.S.	1-3	25. ±4. V AC rms
INPUT P.S.	10-6 REF	17.5 ± .5 V DC
INPUT P.S.	9-6 REF	17.5 ± .5 V DC

A 20,000 ohm/volt multimeter is recommended for the above measurements. In addition, the regulated voltages (DC measurements) should show low ripple (less than 3 mV p-p) on an AC coupled oscilloscope.

5.6 Servicing Malfunctions

The detailed calibration and checkout procedures in Section 4 and the voltage measurements in Section 5.5 should be of great help in pinpointing possible trouble. In addition, standard signal tracing techniques proceeding generally from input to output and making use of the oscilloscope are of great help. The printed circuit cards are also removable, which helps locate short-circuit malfunctions.

If replacement of any component is necessary on a printed circuit board, the excess solder at the points of insertion should first be removed by either a soldering iron and a desoldering wick (Dri-wick-American Electrical Heater Co.) or a desoldering bulb (Ungar #7805 Solder-OFF Bulb). Combinations of soldering irons and bulbs are also available (Ungar Model 7800 Hot-Vac Tool).

Removal of integrated circuits is best accomplished by using a special soldering iron tip designed to fit around the IC pins and an extractor. The excess solder around the insertion points is removed by the method of choice, and the IC pins are then straightened. The card is then clamped in a bench vise, the pins are heated with the special soldering iron tip (Princess 6902 Handle 6918 Heat Capsule, and 6948 tip) and the integrated circuit is pulled out with the extractor.

When the soldering wick is used, the integrated circuit may often be pried out carefully without the use of the special soldering tool.

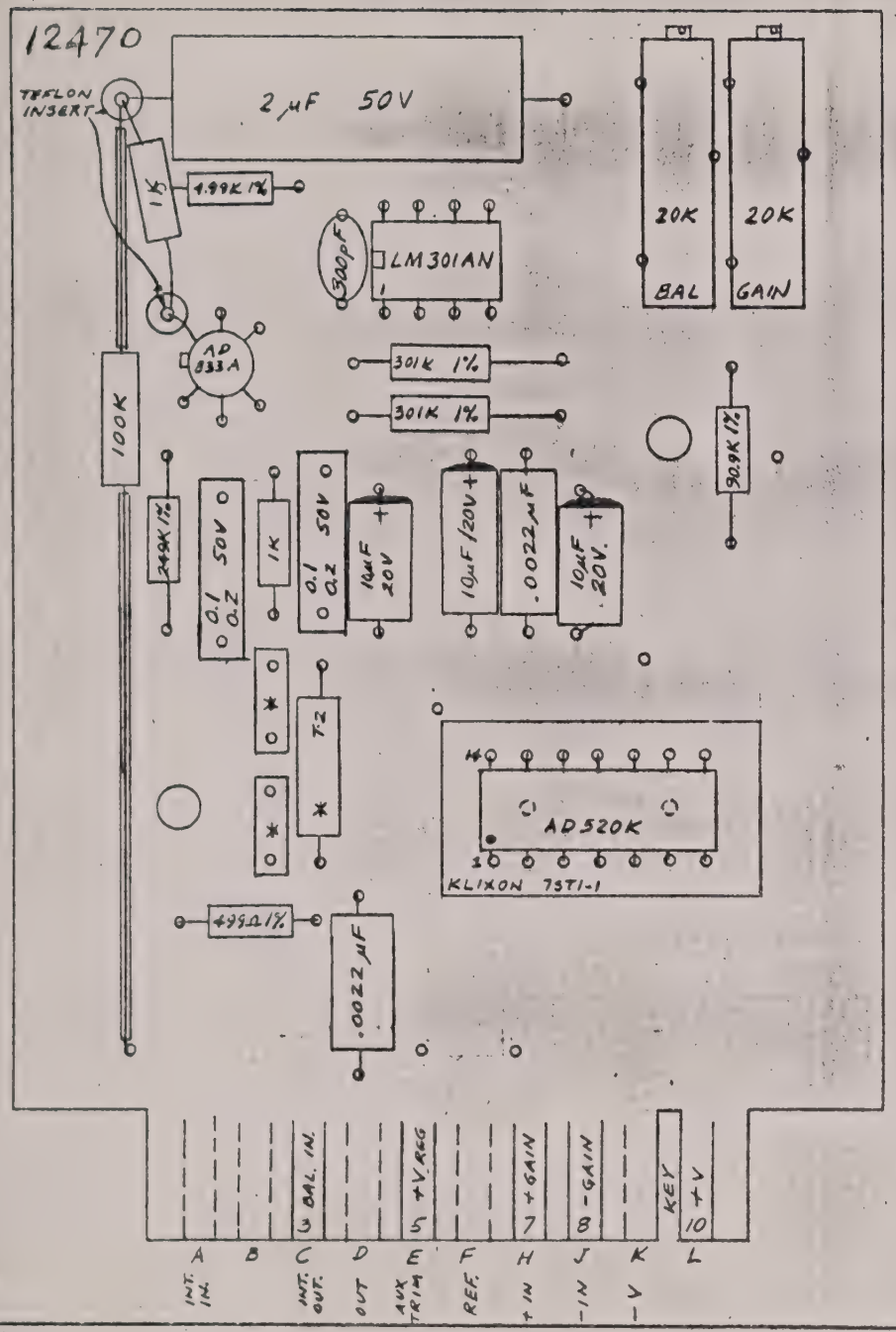
Care should always be taken in removing components to avoid delamination of the conductor from the printed-circuit board.

5.7 Component Location

Figures 5.2 through 5.9 show the component layout for each of the circuit boards.

5.8 Following is ordering information for integrated circuits, semiconductors, and other critical components used in the Model D22. Other resistors and capacitors are widely available from many sources.

PART NO	DESCRIPTION	MANUFACTURER
NE531V	I.C. Op. Amp	Signetics
LM301AN	I.C. Op. Amp	National, Raytheon
AD520K	I.C. Instrumentation Amp	Analog Devices
UGA7723393	I.C. Voltage Regulator	Fairchild (μA723)
AD841	Dual FET	Analog Devices
AD833A	Dual FET - Low Gate Current	Analog Devices
μA726	Temp. Controlled Dual NPN	Fairchild
75T1-1	14 pin oven & connector	Texas Instruments
175Q14111	Thermistor	NL Industries
T1S92	Si. NPN	Texas Inst.
T1S93	Si. PNP	Texas Inst.
2N4922	Power NPN	Motorola
2N4919	Power PNP	Motorola
2N3458	N FET	Siliconix
1N 3581	TC Zener (11.8V)	
1N 914	Si. Diode	
1N 5394	Si. Rectifier	Westinghouse
31-223	Two Conductor BNC (Panel)	Amphenol
31-224	Two Conductor BNC (Cable)	Amphenol
33-101	BNC to Microdot Adapter	Amphenol
DBC 9S	9-Pin Rectangular Connector	Amphenol



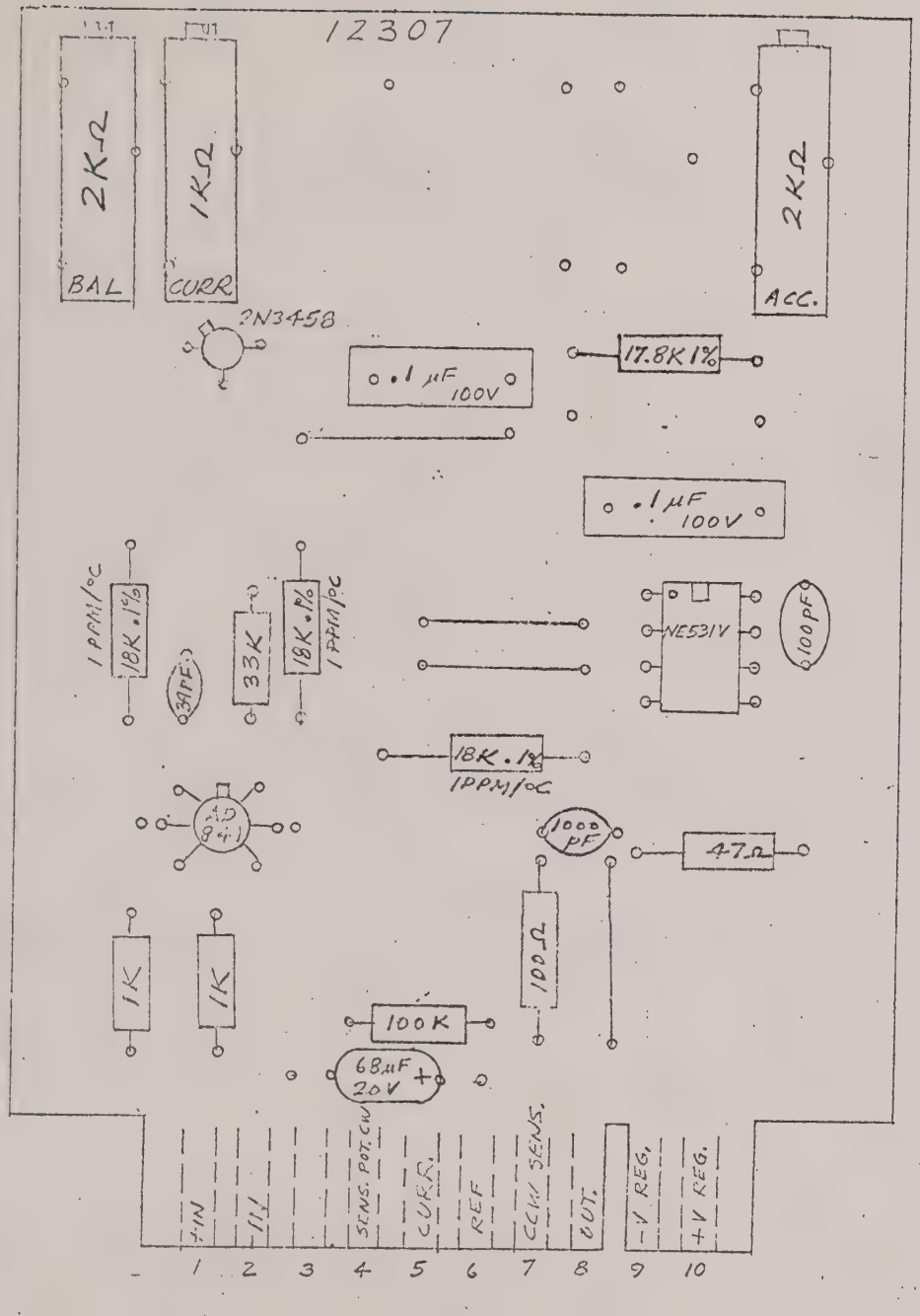
X. ADJUST AT FACTORY 300-500Ω

FIG 5.2

TOLERANCES EXCEPT AS NOTED	UNHOLTZ-DICKIE CORP.
DECIMALS ±	D22PMB SCALE 4X DRAWN BY TU APPROVED BY
FRACTIONAL ±	TITLE COMPONENT LAYOUT DIFFERENTIAL AMPLIFIER
ANGULAR ±	DATE 2/27/74 DRAWING NUMBER C12518

UNHOLTZ-DICKIE CORP.
TOLERANCES EXCEPT AS NOTED
ORIGINAL ±
PROJECTIONAL ±
ANGULAR ±
SCALE
DRAWN BY TV
APPROVED BY
TITLE COMPONENT LAYOUT
3.G. POWER SUPPLY- BRIDGE CONNECTION
DATE 3-4-74
DRAWING NUMBER C12472
12471
20.25V. UNREG.
EXT. SENS. +V
V REFERENCE
EXT. SENS. REF.
V REF RANGE
REF.
+ IN
- IN
+V OUT
+15V REG
1 2 3 4 5 6 7 8 9 10
R4
R3
R2
R1
0.2 μF
+10μF 20V
LM301AN
300Pf
2N4922 METAL CAP WITH HEAT SINK
LT592
4.7Ω
100Ω 2W
11.3K 1%
10μF 20V+
IN3581
680Ω
500
ADJ VOLT

FIG 5.3



D22 PMB

TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP.
DECIMAL ± .1	SCALE
FRACTIONAL ±	TITLE DIAL-A-GAIN AMPLIFIER COMPONENT LAYOUT

DRAWN BY TU

APPROVED BY

FIG. 5.4

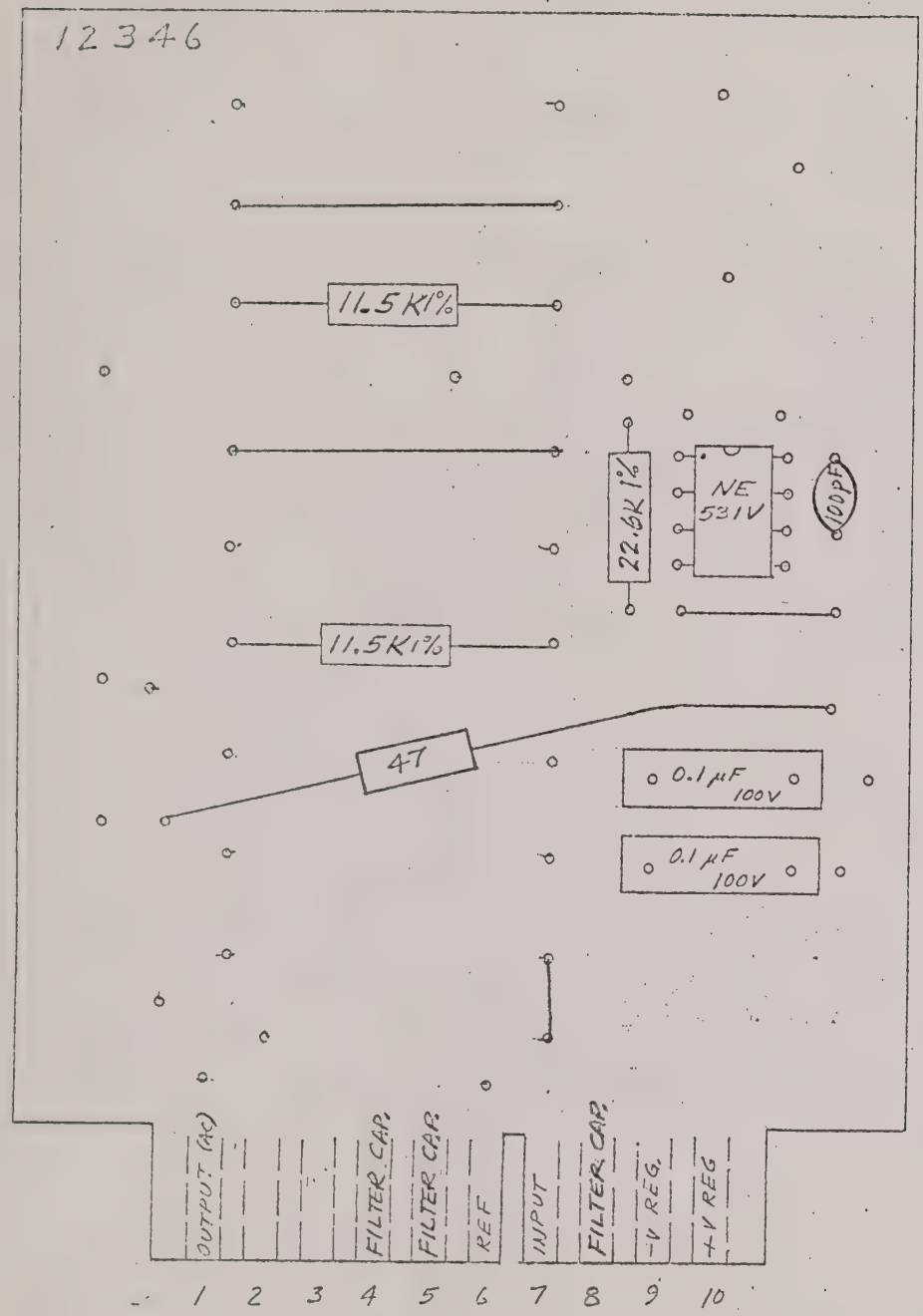


FIG 5.5

D22PMB

TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP.
DECIMAL ±	SCALE — DRAWN TU APPROVED
FRACTIONAL ±	TITLE COMPONENT LAYOUT LOW-PASS FILTER 2 POLE
ANGULAR ±	DATE — DRAWING NUMBER

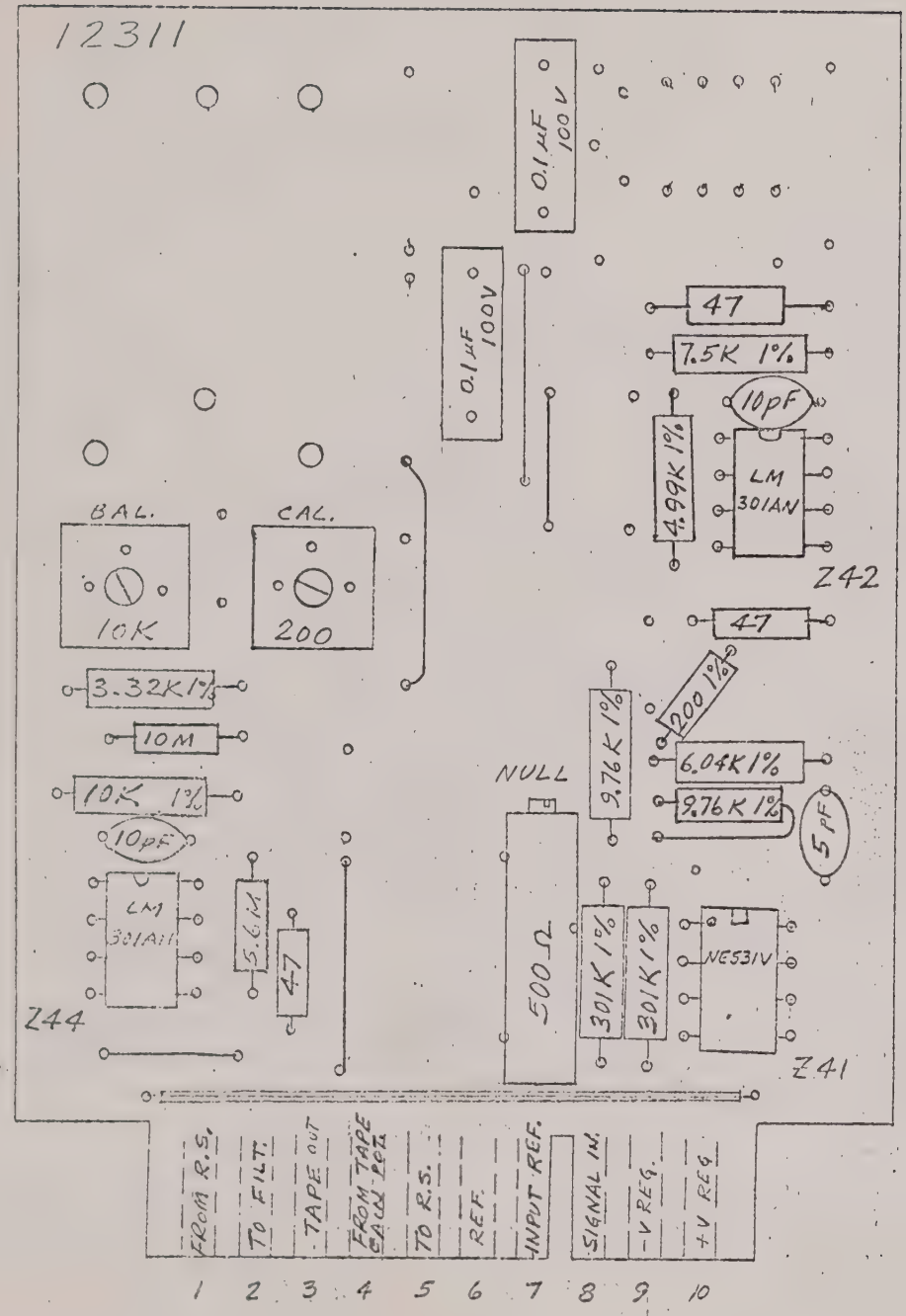


FIG 5.6

D22PMB

TOLERANCES (EXCEPT AS NOTED)	UNIHOLTZ-DICKIE CORP
DECIMAL ±	SCALE 2X
FRACTIONAL ±	TITLE COMPONENT LAYOUT
ANGULAR ±	DATE 9-19-72

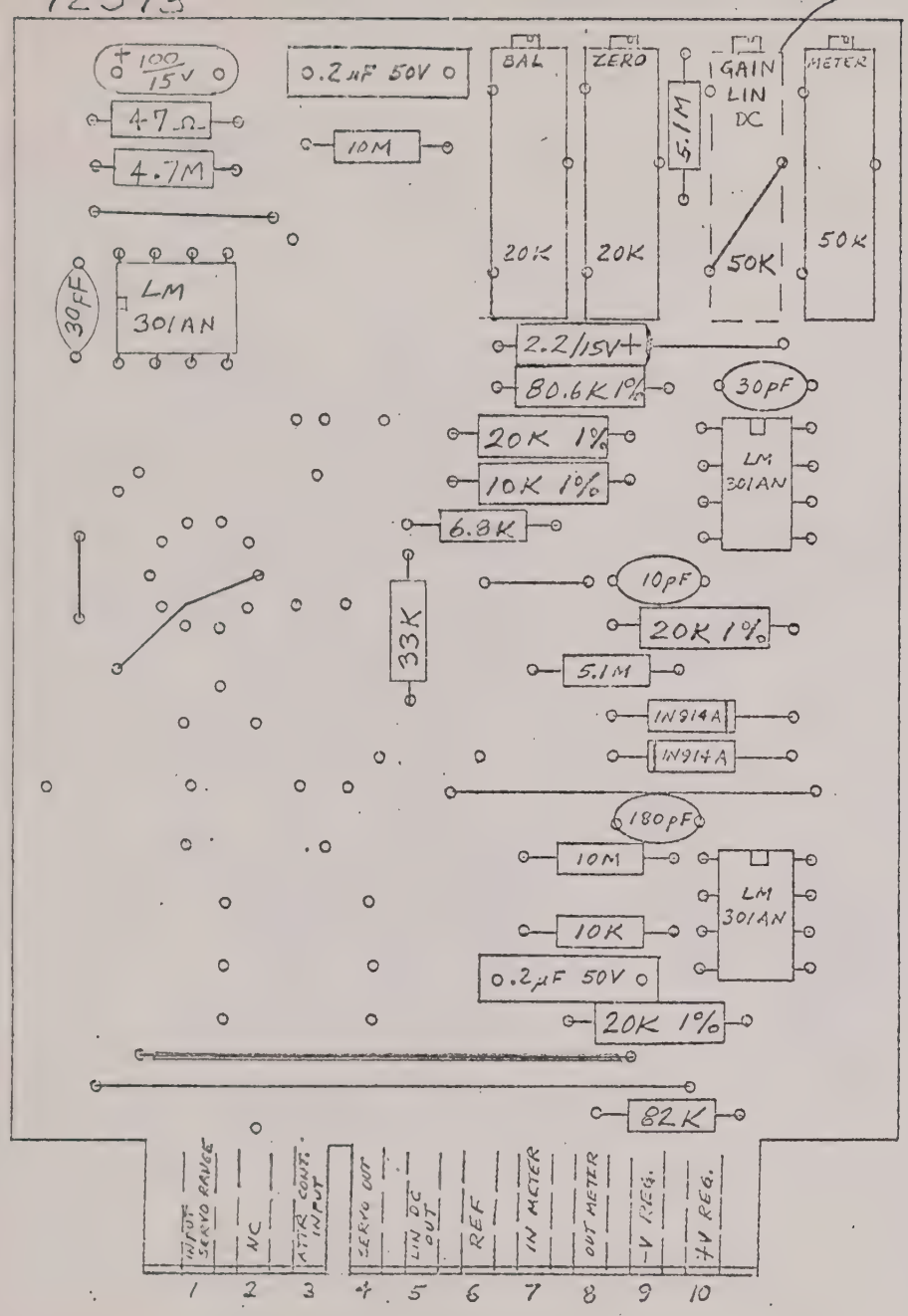
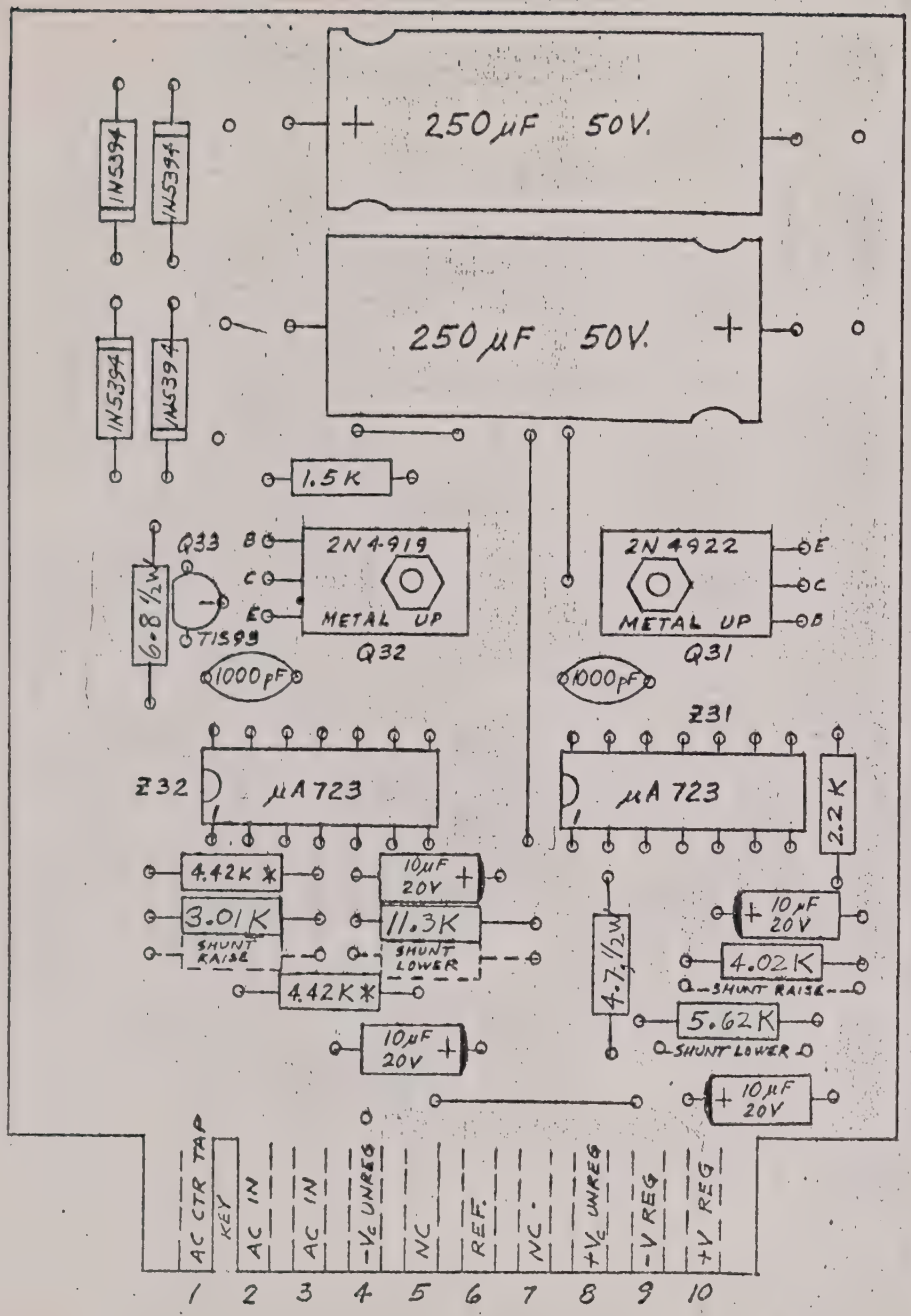


FIG 5.7

D22PMB

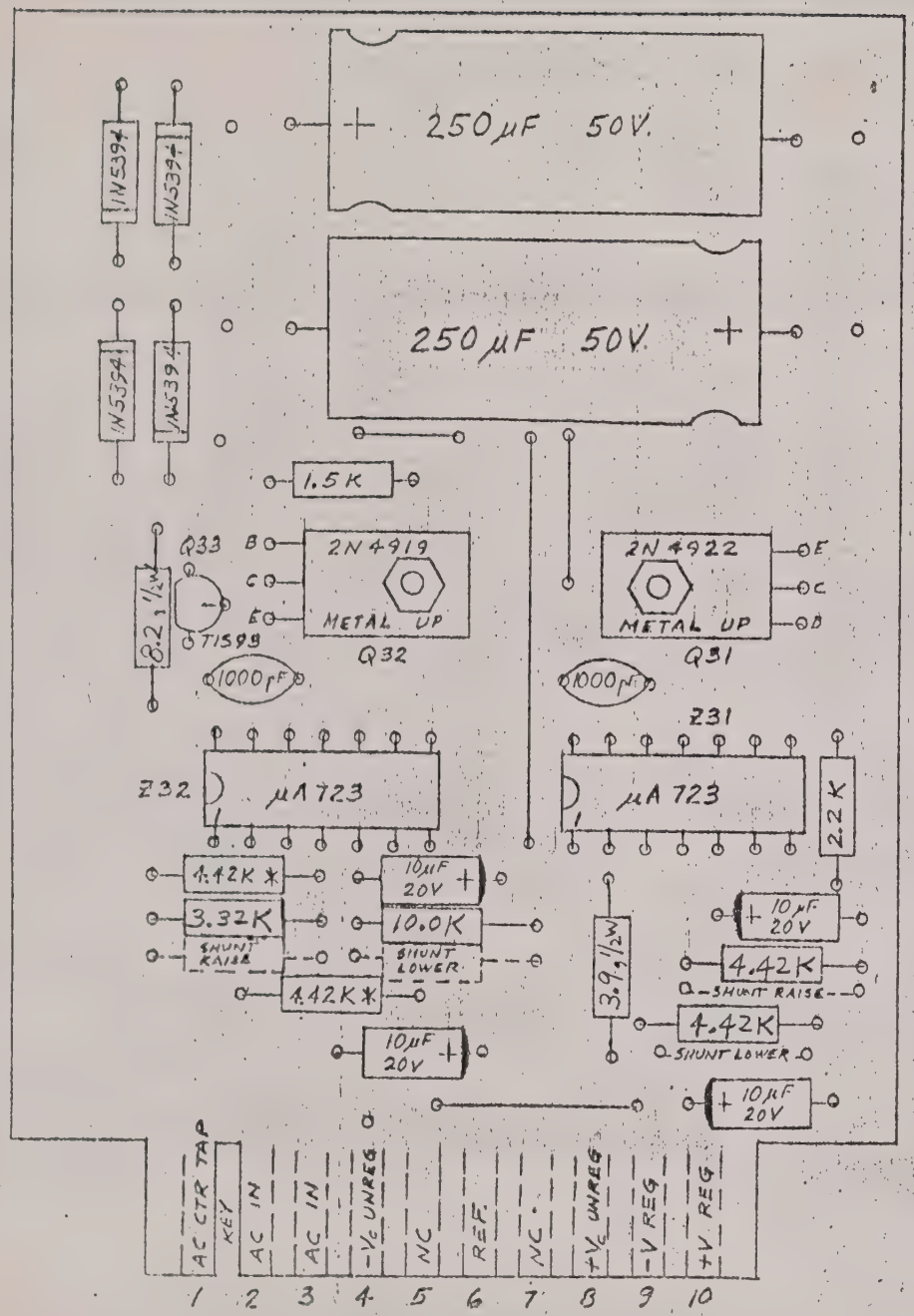
TOLERANCES UNLESS NOTED	UNHOLTZ-DICKIE CORP
DECIMAL ±	SCALE — DRAWN BY TU
FRACTIONAL ±	TITLE COMPONENT LAYOUT METER-SERVO CARD
ANGULAR ±	DATE 10-30-73 DRAWING NUMBER C1237



INPUT POWER SUPPLY

D22PMB

TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP		
DECIMAL ±	±18V	SCALE	DRAWN BY TU
FRACTIONAL ±	TITLE COMPONENT LAYOUT DUAL REG. POWER SUPPLY		APPROVED BY
ANGULAR ±	DATE 10-4-74	DRAWING NUMBER C12310	



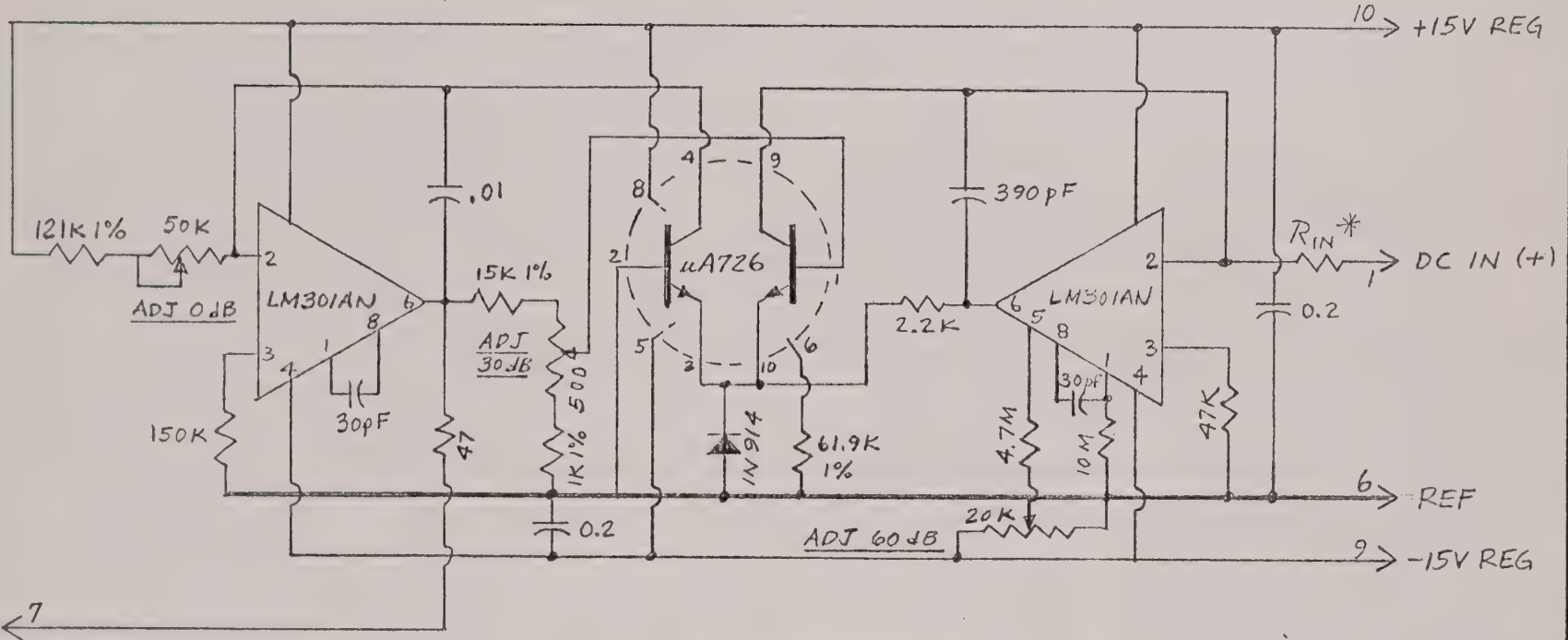
OUTPUT POWER SUPPLY

D22PMB

TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP
DECIMAL ±	±15V
FRACTIONAL ±	TITLE COMPONENT LAYOUT DUAL REG. POWER SUPPLY

FIG 5-5

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.



*

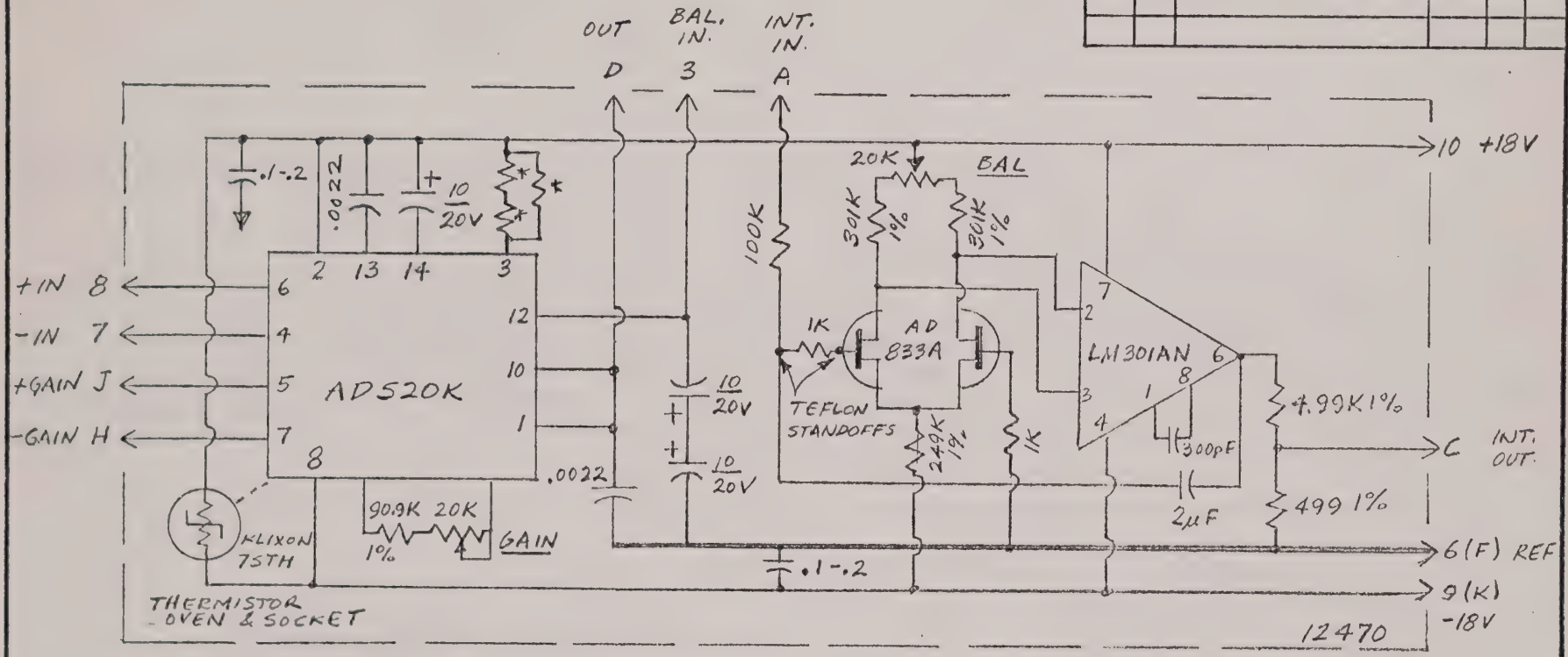
DC IN	5V	10V
R_{IN}	49.9K 1%	100K 1%

TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP		
DECIMAL ±	MOD D22	SCALE —	DRAWN BY TU APPROVED BY
FRACTIONAL ±	TITLE LOG DC CONVERTER CIRCUIT SCHEMATIC		
ANGULAR ±	DATE 5/21/73	DRAWING NUMBER A12410	

CRYSTALENE ® 10 5465

MADE IN U.S.A.

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.

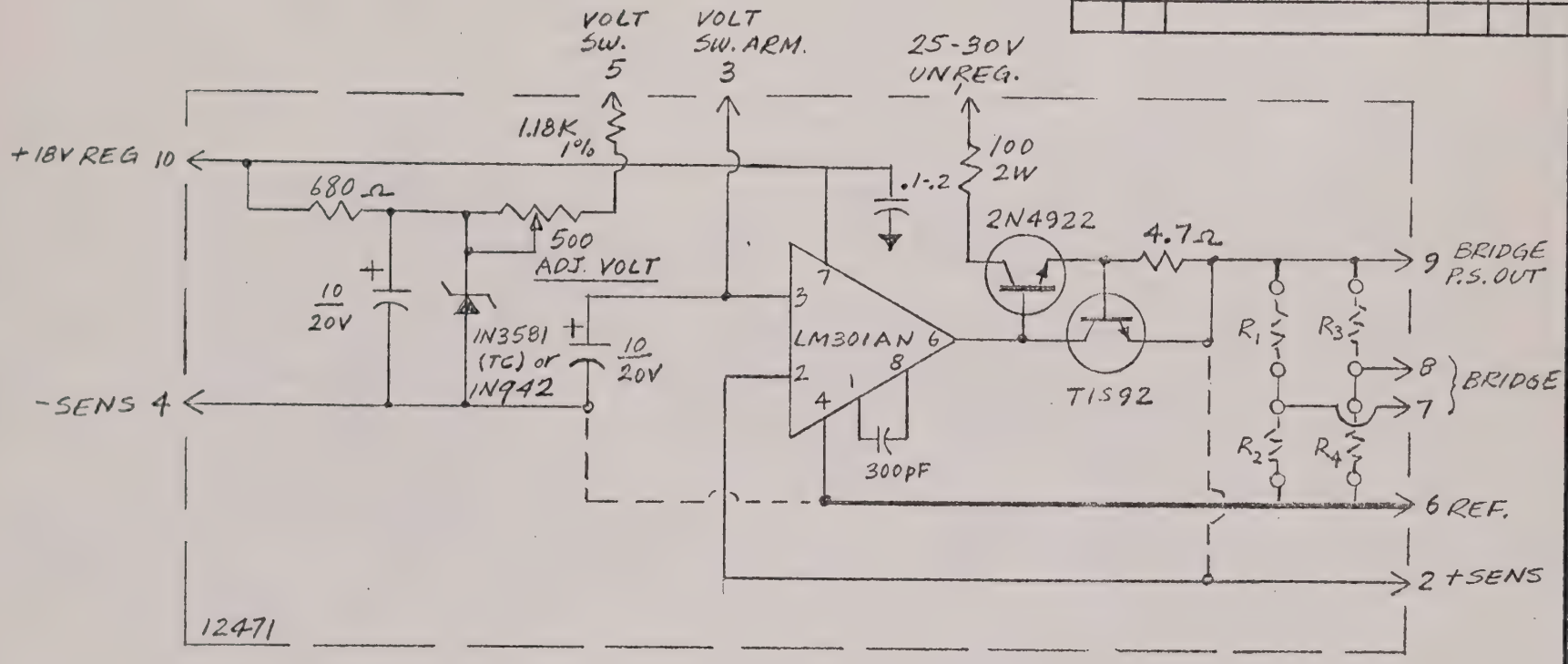


* DETERMINED AT FACTORY
300 - 500 Ω < 5ppM T.C.

TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ - DICKIE CORP		
DECIMAL ± —		SCALE —	DRAWN BY TU APPROVED BY
FRACTIONAL ±	TITLE CIRCUIT SCHEMATIC DC DIFF AMP & AUTO-BAL DRIVER		
ANGULAR ±	DATE 6-7-74	DRAWING NUMBER A 12502	

CRYSTALENE ® 10 5465
MADE IN U.S.A.

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.

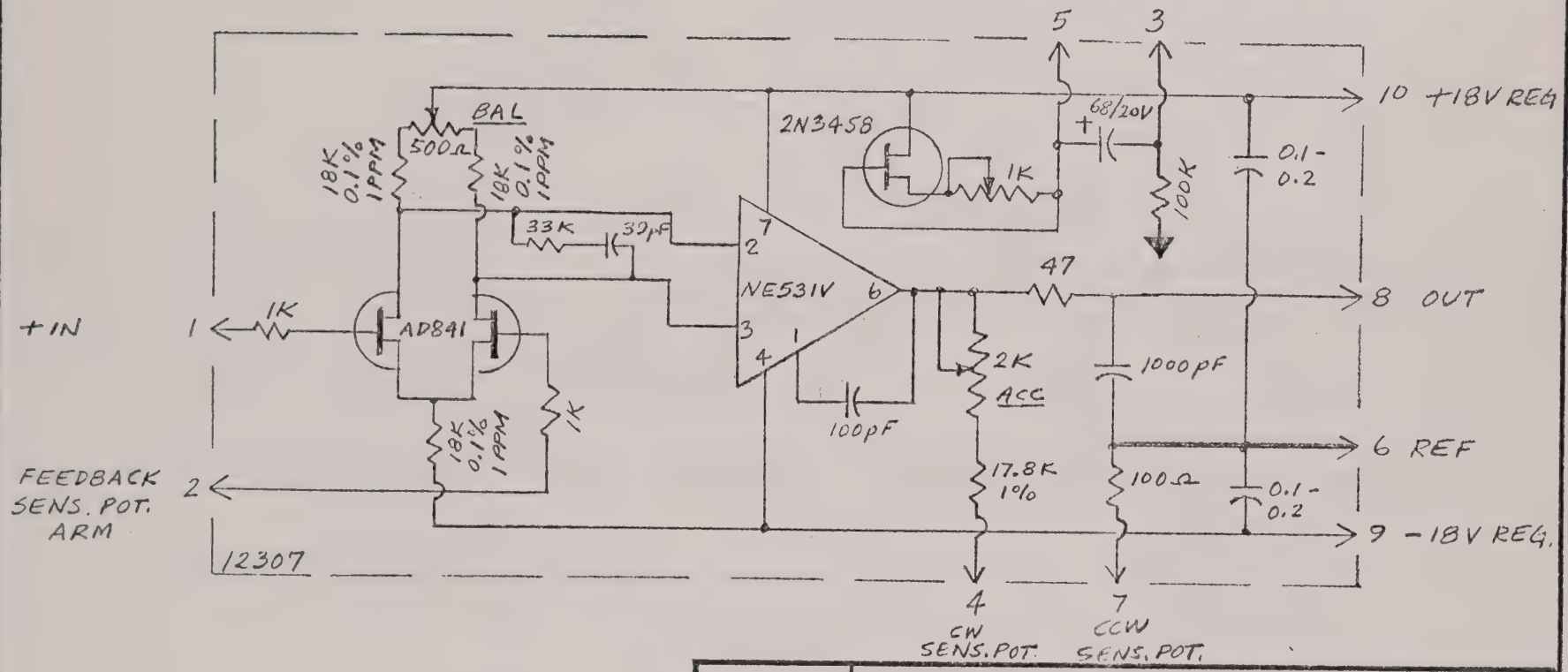


$R_1 - R_2 - R_3 - R_4$ BR. COMPLETION

---------- DENOTES JUMPERS FOR INT. SENSING.

TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP		
DECIMAL ± —		SCALE —	DRAWN BY TU APPROVED BY
FRACTIONAL ±	TITLE CIRCUIT SCHEMATIC BRIDGE POWER SUPPLY		
ANGULAR ±	DATE 6-7-74	DRAWING NUMBER A12503	

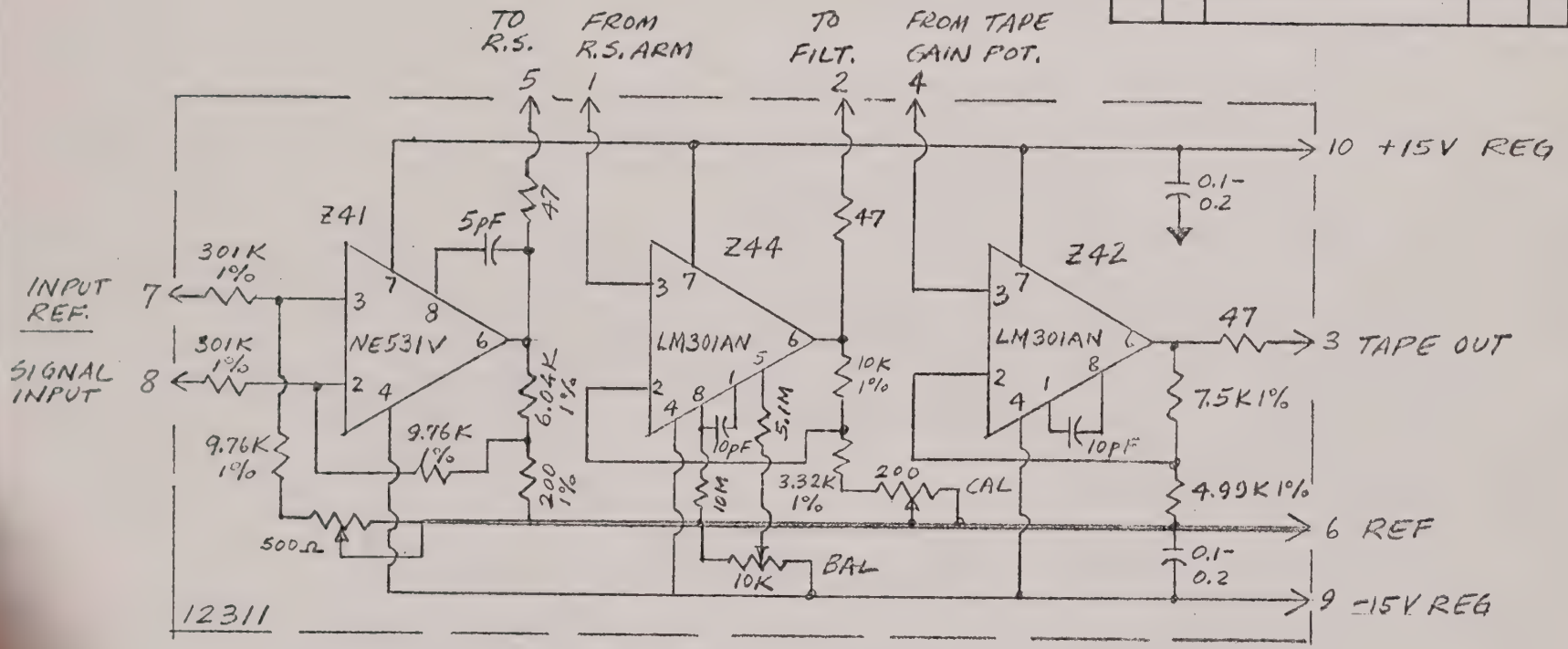
DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.



TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ - DICKIE CORP.		
DECIMAL ± —		SCALE —	DRAWN BY TU
			APPROVED BY
FRACTIONAL ±	TITLE CIRCUIT SCHEMATIC DIAL-A-GAIN AMPL. D22PMB		
ANGULAR ±	DATE 6-7-74	DRAWING NUMBER A12504	

K&E CRYSTALENE ® 10 5465 ENGINEERS' STANDARD FORM
MADE IN U.S.A.

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.



TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP.		
DECIMAL ± ——		SCALE ——	DRAWN BY TU APPROVED BY
FRACTIONAL ±	TITLE CIRCUIT SCHEMATIC DIFF-AMP -TAPE DRIVER D22PMB		
ANGULAR ±	DATE 6-7-74	DRAWING NUMBER A12505	

K&E CRYSTALENE ® 10 5405 ENGINEERS' STANDARD FORM

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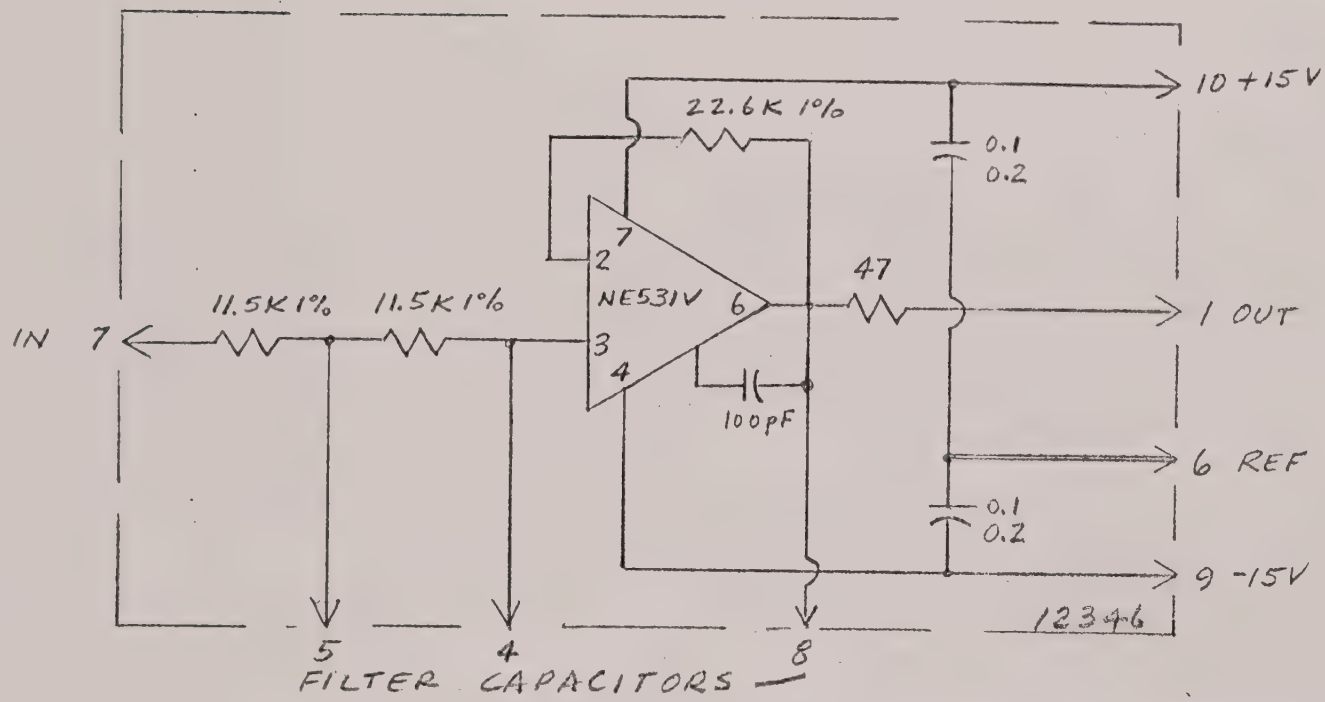
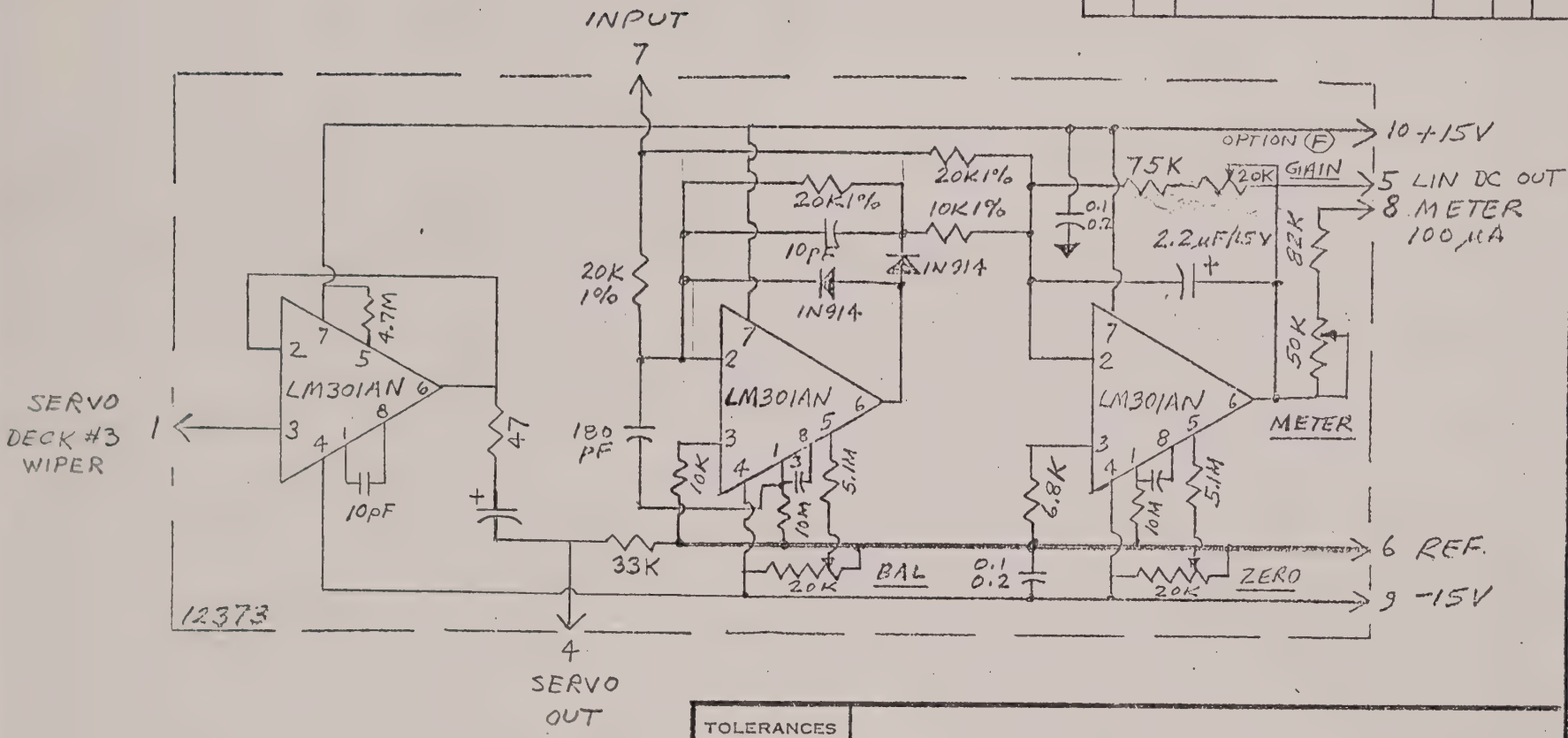


TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ - DICKIE CORP		
DECIMAL ± —		SCALE —	DRAWN BY TU APPROVED BY
FRACTIONAL ±	TITLE CIRCUIT SCHEMATIC FILTER CARD D22PMB		
ANGULAR ±	DATE 6-7-74	DRAWING NUMBER A12506	

K&E CRYSTALENE ® 10 5465
ENGINEERS' STANDARD FORM
MADE IN U.S.A.

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.



TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP		
DECIMAL ± —	D22PMB	SCALE —	DRAWN BY TU APPROVED BY
FRACTIONAL ±	TITLE CIRCUIT SCHEMATIC A-C D-C CONV.- SERVO OPTION		
ANGULAR ±	DATE 6-7-74	DRAWING NUMBER A 12507	

K&E CRYSTALENE © 10 5403 ENGINEERS' STANDARD FORM
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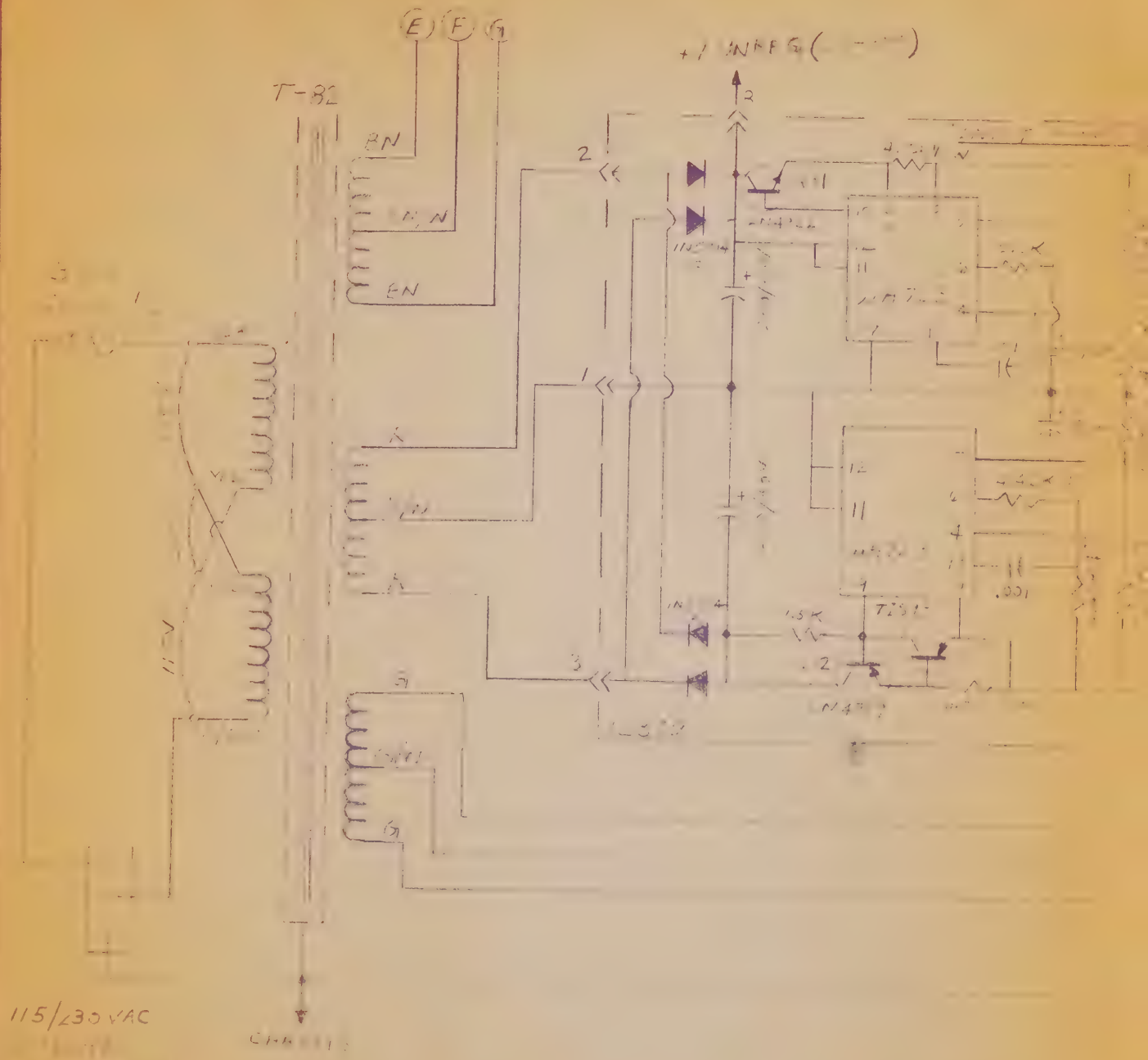
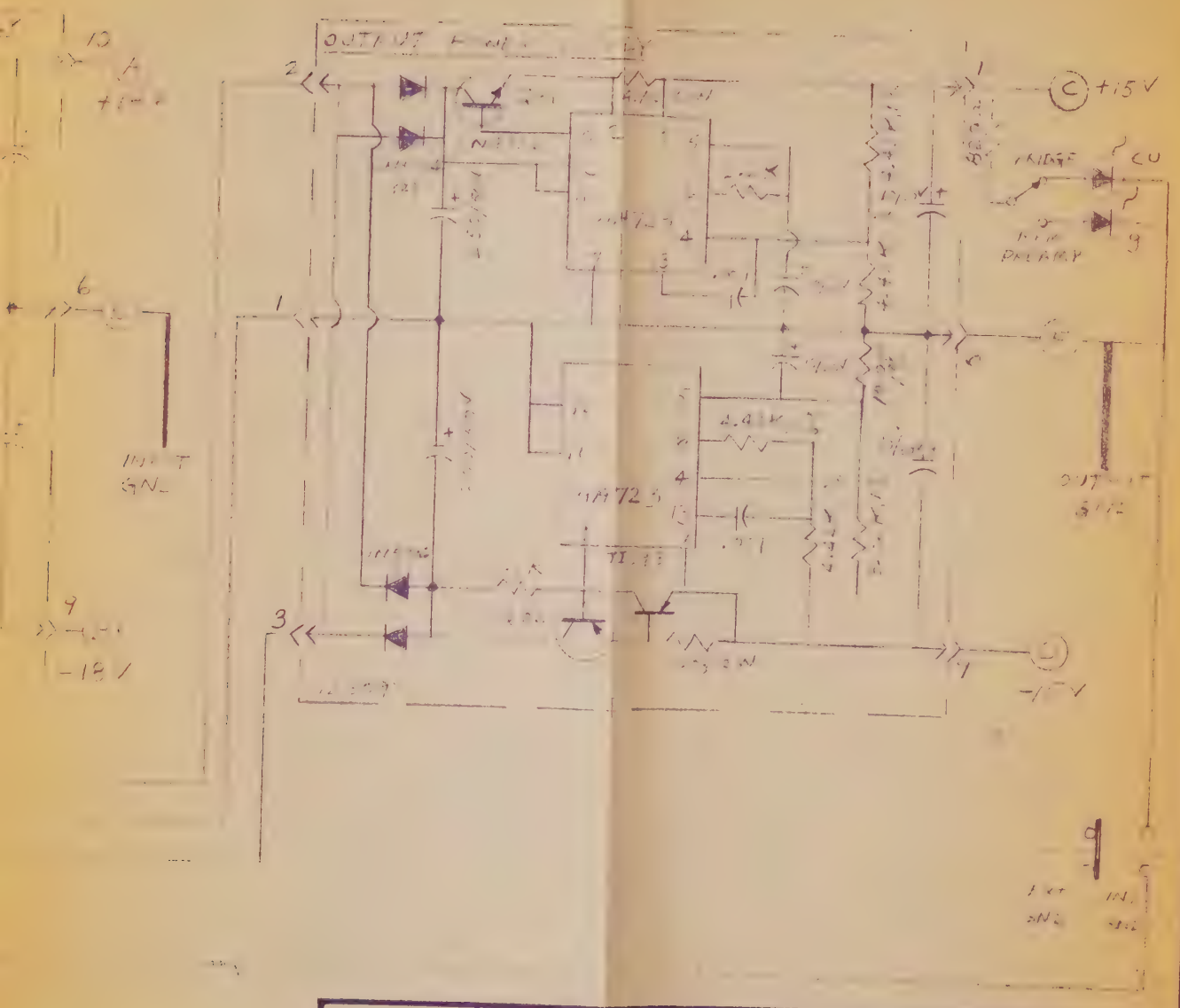


ALBANENE ® No. 546
ENGINEERS STANDARD FORM

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.



TOLERANCES (EXCEPT AS NOTED)	UNLESS DECIMAL ONLY		
DECIMAL ±		SCALE	DRAWN BY TG
			APPROVED BY
FRACTIONAL ±	TITLE POWER SUPPLY CIRCUIT SCHEMATIC		
ANGULAR ±	DATE 1-11-74	DRAWING NUMBER E12547	

MADE IN U.S.A.

A SURVEY OF PRESENT GENERATION SHOCK AND VIBRATION SIGNAL CONDITIONERS

By: Theron Usher, Jr., Unholtz-Dickie Corporation, Hamden, Connecticut

Dr. Usher is presently engaged in signal conditioner development at Unholtz-Dickie Corp. He received the D. Eng. degree at Yale University in 1957 and subsequently has been engaged in university teaching, consulting in the field of underwater signal processing, and in research and development activities for a wide range of projects in the field of vibration testing and measurement. His published work includes a number of technical articles in the above fields. He is a former associate editor for the ASA, and is currently a member of IEEE, IES, and Sigma Xi.

INTRODUCTION

The fields of digital computer technology and signal-processing techniques have experienced a period of explosive growth durthe past decade. The development of analog signal conditioning equipment during the same period has not been nearly so dramatic, but some recent developments, as well as extensions and improvements of older ideas, deserve discussion.

The following areas are covered in this paper:

(1) Mulitpurpose signal conditioners for a variety of input transducers.

(2) Differential charge amplifiers and applications with high-temperature accelerometers.

(3) Automatic range control and remote range control.

(4) Low-frequency, low-amplitude measurements.

(5) Direct-coupled differential amplifiers and bridge conditioners.

The above topics, which are by no means exhaustive, are discussed from the standpoints of application areas, important features, and typical specifications. However, before this discussion is undertaken, typical features of most signal conditioners, and charge amplifiers in particular, are reviewed in the following section. This discussion for many readers will be largely tutorial.

1. TYPICAL FEATURES

General Design

Early multichannel signal conditioners used common power supplies, but modular instrumentation with individual power supplies now constitutes a great majority of acquisitions. Six or more modules fit in a rack adapter for system applications, but single units can also be used for portable laboratory measurements. Power transformers are usually electrically shielded.

Current instrument design utilizes balanced regulated power supplies with short-circuit protection and balanced circuit design employing integrated circuit operational amplifiers wherever possible. This is generally true even for AC coupled designs, because balanced circuit design decouples any possible power supply effects from the signal bus to a high degree, and thus prevents undesirable feedback effects through the power supplies. The balanced circuit design also minimizes switching transients and allows the overall circuit to have a minimum number of coupling capacitors, which reduces the cost of the instrument.

The charge amplifier has evolved to be the conditioner of choice for piezoelectric accelerometers and other capacitive transducers. The primary reason for this is that the overall conversion gain of the transducer-charge amplifier combination is virtually insensitive to the length of the cable between the transducer and conditioner. This is not the case when a voltage amplifier is the signal conditioner, since the overall gain becomes dependent on the loading capacitance of the interconnecting cable.

Low noise, wide frequency range and high slew rate are desirable features of all signal conditioners. For the charge amplifier, high input charge capacity without saturating the input charge converter is also highly desirable.

Noise

Noise specifications are generally given in terms of a component referred to the input plus a component referred to the output so that the conditioner can be evaluated for any gain condition. For the charge amplifier a representative specification might read:

> .005 pC (picocoulombs) rms plus .0015 pC rms/1000 pF input capacitance RTI (referred to input) plus 1 mV rms RTO for a 2 Hz to 20 kHz bandwidth.

The detailed RTI specification is necessary because the equivalent input noise of the charge amplifier increases with transducer capacitance as well as cable capacitance. The signal detectability may easily be calculated once the noise specification is known. For instance, with an accelerometer having a sensitivity of 80 pC/g, and a capacitance of 1000 pF (Unholtz-Dickie Model 75D21) with a 30 foot cable (1000pF) the wideband acceleration noise RTI due to the charge amplifier is:

$$g_n = \frac{.005 + 2(.0015)pC}{80\ (pC/g)} = 10^{-4}\ g\ rms$$

Thus 10^{-3} g can easily be measured with a signal-to-noise ratio fo 20 dB.

Wideband Characteristics

Wide frequency range implies uniform frequency response over the range but does not necessarily assure full output can be maintained over that range. The amplifier output should be able to slew fast enough to reproduce large high-frequency transients. Typical frequency response specifications are:

±5% 2 Hz to 30 kHz, ±1% 10Hz to 10 kHz

The charge amplifier output should generally be capable of providing 10V peak at 20 kHz which corresponds to an output slew rate of 1.25 V/μsec since:

Slew Rate = $2\pi\ f_{upper}\ V_{peak} \times 10^{-6}$ V/μsec

The maximum input charge for a charge amplifier is determined by the characteristics of the input charge converter. A typical charge converter has a 1 mV/pC transfer ratio and 10 V peak output without saturating. Thus a charge of 10^4 pC may be handled at the input without saturating the input converter. Saturating the input converter can cause loss of signal due to long recovery time. For an accelerometer having a sensitivity of 10 pC/g, this corresponds to a peak acceleration of 1000 g. A typical slew rate for a charge converter is 6 V/μsec (10 V output at 100 kHz). For reference a simplified block diagram for a charge amplifier is shown in Fig. 1.

Transducer Sensitivity Noramlization

It is desirable to have the rated value of the ranged output of a signal conditioner represent the same full-scale physical input values regardless of the transducer sensitivity or transfer ratio. A necessary feature to accomplish this is the gain-normalizing amplifier in Fig. 1. The gain normalization function is usually accomplished by a multi-turn precision potentiometer which adjusts the feedback ratio of the gain-normalizing amplifier. The transducer sensitivity is set directly on the turns-reading dial of the potentiometer, which automatically provides a signal conditioner gain which is inversely related to the transducer sensitivity.

A typical charge amplifier is designed to accept transducer sensitivities from 1 pC/g to 100 pC/g in two 10:1 ranges. The significant digits of the sensitivity are set on a ten-turn locking dial. Rated output is typically provided for full scale inputs from 1g to 1000g, although extension of this range by 10:1 at either end is not uncommon.

Ground Signal Rejection

In many cases a ground loop can exist because the transducer case is attached directly to the metallic test structure and the test structure is connected electrically to the reference bus of the instrumentation. Refer to Fig. 2. In many cases there is a significant voltage which exists across this electrical connection because of long length, magnetic fields, and ground return currents. The resulting current through the shield of the transducer cable establishes an undesirable signal voltage, which is fed to the input converter through the capacitance of the cable and transducer. This input is amplified by the signal conditioner to produce a large undesirable output.

A simple remedy is, of course, to insulate the transducer case from the structure, but this may not be physically desirable or possible. An alternate solution which allows the direct connection of the transducer to the structure can be had by separating the reference for the input amplifiers and output amplifiers at "X" in Fig. 2 and feeding the signal on the input reference bus to a differential connection on the output amplifiers. This interrupts current I and prevents the ground signal voltage V from feed-

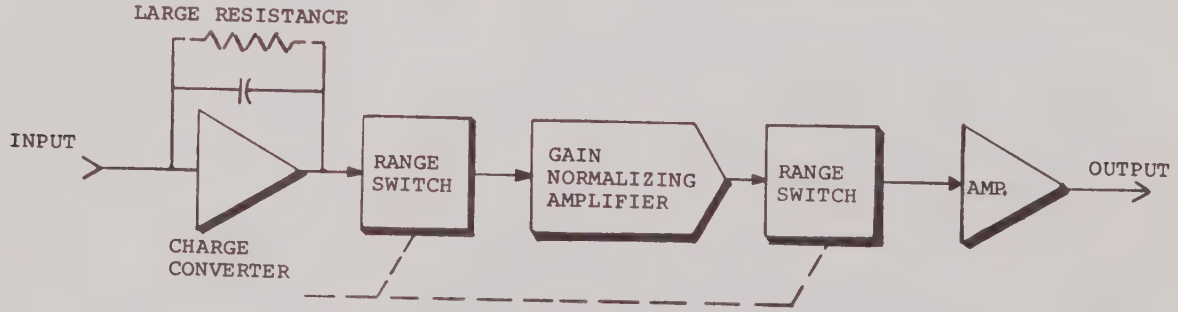


FIG. 1 SIMPLIFIED BLOCK DIAGRAM FOR CHARGE AMPLIFIER

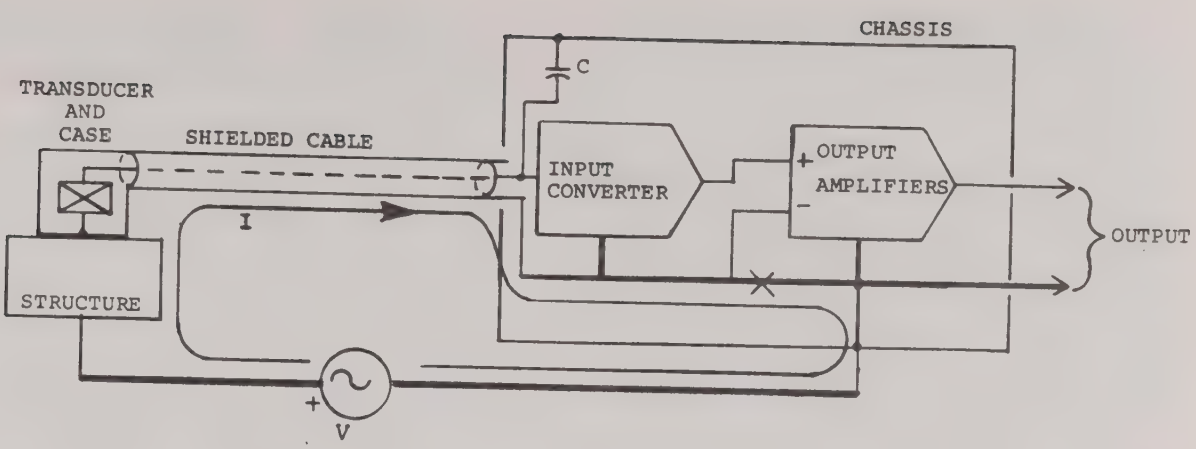


FIG. 2 EQUIVALENT CIRCUIT WITH TRANSDUCER GROUNDED AT TEST STRUCTURE

ing through the cable capacitance. Care must be taken in guarding the input converter so that the capacitance C from chassis to input is minimized. Rejection of the input ground signal for charge amplifiers is typically better than 50-60 dB.

A two-position switch is usually provided in most single-ended conditioners to accommodate either isolated or grounded transducer cases.

Remote Preamplifiers

Excessively long cables from the transducer have several disadvantages:

(1) The signal-to-noise ratio decreases with length (note the noise specification for charge amplifiers).

(2) For capacitive transducers, triboelectric noise can be a problem, even with treated cables.

(3) Low-noise cables are comparatively expensive, and some commonly-used varieties are not particularly resistant to abuse.

A remote preamplifier, used instead of the internal charge converter, removes most of these objections because it can be located close to the transducer. The cable between the preamplifier and the conditioner can then be an inexpensive, sturdy coaxial variety in which the center conductor not only carries the signal voltage but also the operating voltage and current for the preamplifier. Triboelectric noise is not a problem because of the low source impedance of the output of the remote preamplifier.

Provision for using either the internal converter or a remote preamplifier by means of a switch has been a desirable feature for signal conditioners. The preamplifier power supply is included in the signal conditioner.

Miscellaneous Features

Many signal conditioners provide for a variety of low-pass filters, since there may be no need to measure over the entire frequency band of the conditioner, and maximum signal-to-noise ratio is desired. High-pass filtering is discussed in a later section.

Some means for providing full-scale output calibration and a test of the cable and transducer integrity is often provided.

Optional features on signal conditioners can also include:

(1) Constant sensitivity output (i.e. 10 mV/g) for control of vibration tests.

(2) High-current drivers for galvanometer recording and driving long lines.

(3) Meter indication.

(4) Logarithmic (DC) conversion of the output for plotting purposes.

2. MULTIPURPOSE SIGNAL CONDITIONERS

Several years ago facilities which had cause to work with a large variety of transducers, such as piezoelectric accelerometers, servo accelerometers, piezoresistive accelerometers, strain gages, thermocouples, etc., required several different instruments to accommodate the measurement tasks. This proved to be expensive, especially if the individual utilization time of the separate instrument happened to be low. The solutions to this problem which have evolved are based on the observation that some portion of the electronics for the different instruments is quite similar.

One solution has been to provide and instrument main frame with the necessary power supplies, input connectors and output connectors. Plug-in cards with attached front panels and supplementary controls provide the condition-

ing requirements for each separate application, and include a charge amplifier, a bridge conditioner with amplification, a carrier amplifier and other bridge conditioners.

Another recent solution has been to provide an instrument main frame with the necessary power supplies, direct-coupled post-amplifier, meter, gain controls, input connectors and output connectors. Separate plug-in chassis provide the necessary conditioning for capacitive transducers (charge converter),servo accelerometers, and bridges with 1, 2, or 4 active arms. The separate plug-in chassis also contain front panel controls for gain normalization and calibration.

A third solution, which differs somewhat from the so-called "Universal Signal Conditioners" described above, provides a single instrument (U-D Model D22PMR), shown in Fig. 3, with front-panel switching for the following applications:

(1) Charge amplifier for piezoelectric accelerometers, force gages, and pressure transducers.

(2) High input-impedance voltage amplifier for general applications.

(3) Direct inputs from single strain gages for dynamic strain measurement.

(4) Inputs from remote preamplifiers.

All four applications above are provided by changing connections to the input converter or by rerouting the signal past the input converter (application 4). In addition, the strain-gage mode of operation provides the selection of several accurately-determined values of constant-current excitation for the strain-gage. The current is applied through the center conductor of the connecting cable.

FIG. 3 MODEL D22PMR
MULTIPURPOSE SIGNAL CONDITIONER

The feature of sensitivity normalization is preserved for all modes of operation. The explanation of how this is accomplished for the strain-gage mode follows. The gage factor F is defined by:

$$F = (\Delta R/R)/(\Delta L/L) \qquad (1)$$

where $\Delta L/L$ is strain and ΔR is the change of resistance for gage resistance R. The change in output voltage for the gage with constant current excitation is

$$\Delta V = \Delta RI \qquad (2)$$

The gage transfer ratio or sensitivity S is defined by

$$S = \Delta V/(\Delta L/L) \qquad (3)$$

Substituting (1) and (2) in (3) yields

$$S = FRI \quad \text{millivolts/millistrain} \quad (4)$$
or mV/1000 microstrain

Since F and R are accurately determined by the gage manufacturer and I is accurately (±1%) determined by a switch setting on the conditioner, a sensitivity is easily calculated and set on the gain-normalization dial.

For example, if F = 2.00, R = 120 ohms, and I = 40 ma, we have S = (2)(120)(.040) or 9.60 mV/1000με.

Transducer sensitivities from 1 to 100 mV/engineering unit can be accommodated. (Here one engineering unit(eu) is 1000 με, 1 g, 1 psi, etc.) Ranging is provided for full-scale inputs from 1 to 1000 eu for the charge or voltage mode, and from 10 to 10000 με in the strain-gage mode. Noise in the strain-gage mode is typically less than 0.5 με rms RTI for the numerical example above.

A multivibrator can also be activated to dynamically shunt a preselected resistance value across the strain gage. The peak-to-peak value of the simulated square wave strain can easily be calculated and used as a check on the calibration of the instrument.

The third multipurpose signal-conditioner described above does not provide the exceptionally wide application range that the "Universal Signal Conditioners" provide, particularly for bridge measurements, but it does provide a means for making the most commonly used dynamic measurements. Also, only one instrument is required rather than one main frame and several plug-in panels.

3. DIFFERENTIAL CHARGE AMPLIFIERS

High-Temperature Measurement

Applications for monitoring vibrations of such sources as jet engines, nuclear power plant components, and automobile mufflers have required high-temperature accelerometers. Accelerometers have been developed for measurements at temperatures as high as 1400°F, but the shunt resistance of such accelerometers decreases to the vicinity of

10 kilohms at this temperature. Typically, the shunt resistance of high-temperature accelerometers decreases by a factor of 5-10 for a 200°F increase in temperature above temperatures of 700°F.

Some high-temperature accelerometers have also been constructed so that the crystal is isolated from the case, whereas the conventional lower-temperature accelerometer is constructed with one side of the crystal common to the case. The isolated construction requires a balanced two-wire signal connection with the shield preferably connected to the case. The balanced configuration is apparently an outgrowth of the situation that electrostatic shielding is often not very good in certain areas for high-temperature vibration-monitoring applications. The balanced line offers the best possibility for power frequency harmonic rejection.

High-temperature accelerometers have thus caused the following design changes and emphases in charge amplifiers:

(1) The input charge converters have been redesigned so that they will not saturate or block due to low resistances across the input.

(2) The noise due to the input charge converter at low frequencies must be extremely low, since this noise is emphasized by decreasing input shunt resistance.

(3) High-pass filters have been added to charge amplifiers to sharply cut off the spectrum below the minimum signal frequency to maximize the signal-to-noise ratio.

(4) Differential charge converters have been designed to accommodate the isolated-crystal accelerometers.

Noise Characteristics

The relative noise spectrum (RTI) for a differential charge amplifier with a very large value of shunt resistance is shown in Curve A of Fig. 4. Note that the spectrum rises slightly at low frequencies, which is characteristic of the high-quality FET selected for the input device in the charge converter.

When a relatively low value of shunt resistance (50 kilohms) is placed across the input of the charge converter, the closed-loop forward gain of the device is not markedly affected, but the loop-gain of the charge converter is markedly decreased at the lower frequencies due to the low value of R_s. The effect is to cause the noise spectrum to increase at 1/f rate above curve (A) as frequency decreases. The frequency at which the spectrum begins to deviate from curve (A) is determined by:

$$f_c = 1/(2\pi R_s C_f) \qquad (5)$$

Where R_s is the shunt resistance and C_f is the feedback capacitance of the charge converter. For R_s = 50 KΩ C_f = 1000 pF, f_c = 3180 Hz. Curve (B) in Fig. 4 shows the effect described.

Curve (B) also shows the effect of a three-pole Butterworth high-pass filter (-3 dB at 10 Hz) placed after the charge converter. The decrease in effective noise RTI below 10 Hz is due to this filter. Numerical integration of the square of Curves (A) and (B) from 1 Hz to 20 kHz reveals that the rms value of the wideband noise for Curve (B) is approximately 10 times that for curve (A).

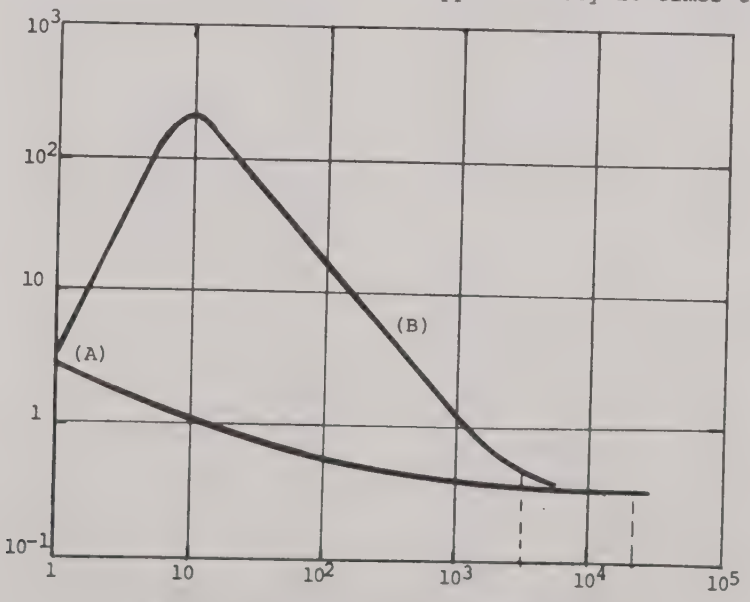


FIG. 4 RELATIVE NOISE SPECTRA FOR CHARGE CONVERTER WITH SHUNT RESISTANCE

A typical specification for the noise under the conditions for curve (B) is a maximum of .05 pC rms (U-D Model D22PMH). If the cut-off frequency for the high-pass filter can be increased for any reason, the low-frequency noise that is seen under conditions of low shunt resistance can be decreased. It is interesting to note that shunt capacitance at the input to the charge converter also increases the noise (RTI) of the charge converter, but in this case the spectral level is increased uniformly at all frequencies.

Differential Charge Converter

The differential charge converter is schematically shown in Fig. 5, along with other input parameters. It can be shown that the output voltage V_o is:

$$V_o = -\frac{Q}{C_f} + \frac{V_2C_2(C_1+C_3+C_f)-V_1C_1(C_2+C_4+C_f)}{C_f(C_1+C_2+C_3+C_4+2C_f)} \qquad (6)$$

In Eq. 6 the first term represents the desired output from the accelerometer and the second and third terms represent the undesirable outputs from the power frequency (hum) sources V_1 and V_2. The capacitances C_1 and C_2 represent stray pickup capacitances for the power frequency voltages and C_3 and C_4 represent line-to-shield capacitances.

The signal-frequency gain of the charge converter is not dependent on the relative values of C_3 and C_4 if the gain of the differential amplifier is very high. However, the ability of the charge converter to reject power frequency signals due to the pickup through the stray capacitances C_1 and C_2 is critically dependent upon the external circuit parameters. In general, the second and third terms of Eq. (6) come close to cancelling each other only if the lines are well-balanced ($C_3 \approx C_4$), the stray capacitances are very nearly equal ($C_1 \approx C_2$) and the hum sources are equal or are the same source ($V_1 \approx V_2$). The analysis leading to Eq. (6) is based on the assumption that the differential amplifier in Fig. 5 itself has perfect common mode rejection.

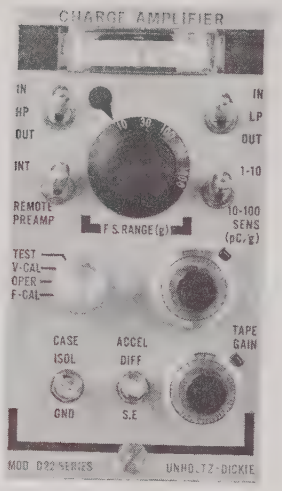


FIG. 6 MODEL D22PMH
DIFFERENTIAL CHARGE AMPLIFIER

Fig. 6 shows the front panel for the U-D Model D22PMH with front panel switches to control high and low-pass filtering, case isolation or grounding, and differential or single-ended charge conversion.

4. AUTOMATIC AND REMOTE RANGE CONTROL

The development of new aircraft, spacecraft and other large structures has required large instrument arrays for simultaneously monitoring motions and stresses on all parts of the test structure. Manual control of large instrument arrays is an almost impossible task for such situations.

Instruments have been developed for which the functions of full scale ranging, calibration, and transducer sensitivity normalization are completely controlled by digital means. However, it is the feeling of this author that such instruments require a large number of control lines and are wasteful of computer memory. Their utility as single-channel portable monitors is also questionable.

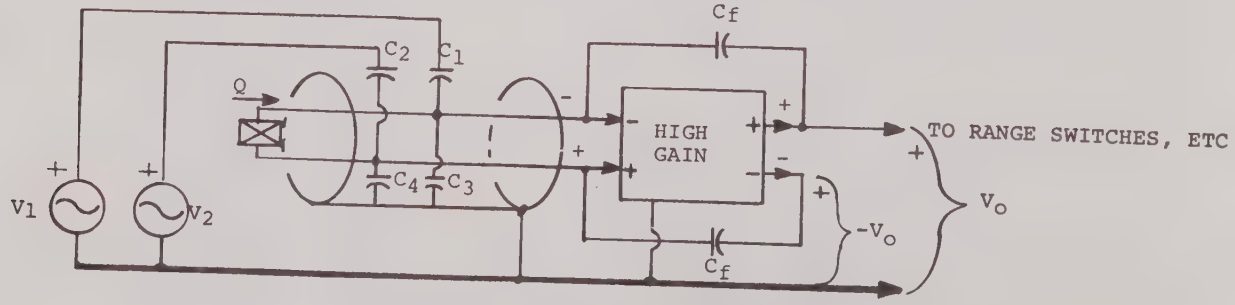


FIG. 5 EQUIVALENT CIRCUIT FOR
DIFFERENTIAL CHARGE CONVERTER

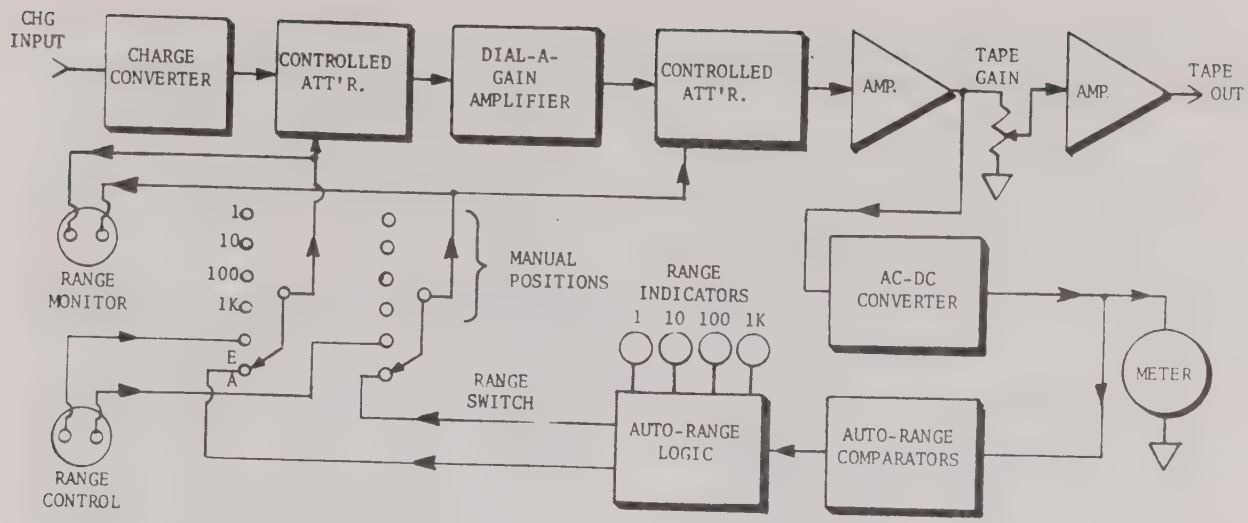


FIG. 7 BLOCK DIAGRAM MODEL D22PMA
AUTORANGING CHARGE AMPLIFIER

Fig. 7 portrays the block diagram of an instrument (U-D Model D22PMA) that serves equally well in large arrays or singly as a portable monitor. The availability of CMOS switches coupled with simple TTL logic, allows the full-scale range to be manually controlled, externally controlled by only two lines, or automatically controlled to the best of four different values. Transducer sensitivity normalization is accomplished by the conventional front-panel technique, and calibration (not shown) is accomplished by relay control. Two-line (binary signal) range monitoring is available for the manual, external, or automatic modes of range control.

Most FM recorders have a 45-50 dB dynamic range. Two-line control or monitoring provides four ranges at 20 dB intervals. This allows an 80 dB range of signals to be recorded, with the minimum recorded signal 25-30 dB above the noise floor of the recorder.

Storage of transducer sensitivity information in a computer for the purpose of compensating data amplitudes appropriately or for the purpose of digitally controlling a compensating circuit in the instrumentation channel is a waste of computer memory or a gross waste of control lines. Normalizing instrument gain to 1% accuracy for a 100:1 range of transducer sensitivities can require from 7 to 13 lines per channel, depending on the method used.

For large arrays, it is much simpler to use accelerometers with closely adjusted sensitivities. A typical example is the U-D Model 10B10 with a charge sensitivity of 10 pC/g ±1%. The sensitivity settings can then be made and locked on all instruments to identical values. Replacement or interchange can be done without affecting system accuracy, and without causing possible errors due to system parameters failing to be reprogrammed or reset.

For each array only one additional line is required to trigger the relay power supply and cause simultaneous full-scale calibration for all channels in the array. For large arrays the number of external range control and/or monitoring lines can be reduced further, because one instrument can be connected to control the full-scale range of several others in a master-slave arrangement.

5. LOW FREQUENCY, LOW AMPLITUDE MEASUREMENTS

Modal testing of large structures often requires the detection of low-frequency mode shapes at necessarily low acceleration values. This also means that the noise level of the transducer and signal conditioning device must be exceptionally low.

A new solution to this problem (U-D Model 500PA) involves close coupling a high-sensitivity piezoelectric accelerometer and an exceptionally low-noise voltage amplifier in a single housing. The accelerometers are carefully screened for minimum sensitivity to thermal transients, and are of shear design to assure insensitivity to base bending and case effects. The voltage

amplifiers have exceptionally low noise and exceptionally low input leakage current to allow flat frequency response to 0.1 Hz (3dB down at .01 to .02 Hz).

The overall sensitivity of the active transducer is from 0.5 to 1.0 V/g and can easily be adjusted to a tolerance of ±1%. The four-wire connection to the transducer supplies positive and negative power supplies, signal output, and signal reference. Since the output impedance of the preamplifier is low, an inexpensive cable can be used which is abuse-resistant, and triboelectric noise is negligible.

The signal conditioner can be a relatively inexpensive device which provides the power supply voltages, different full scale ranges, and low-pass filtering. Full-scale ranges of .01g to 10g are typical with a wideband equivalent input noise of 3×10^{-5}g rms from 1 Hz to 2 kHz. The frequency response of the conditioner must also be flat from 0.1 Hz to the desired upper frequency.

6. DIRECT-COUPLED DIFFERENTIAL AMPLIFIERS

Direct-coupled differential amplifiers find wide application for use with thermocouples, piezoresistive accelerometers, and strain gage bridges. Bridge transducers are used to provide means for measuring accurate zero frequency response as well as for simulating variables that are not physically measurable with a single strain gage, such as shear strain.

Features

A direct-coupled differential amplifier that is designed primarily for bridge transducers should have several additional features in addition to meeting typical specifications for a differential amplifier. These features include:

(1) Internal provision for bridge completion resistors so that bridges with 1, 2 or 4 active arms may be used. Preferably the bridge completion resistors are on a plug-in card.

(2) Inclusion of an accurate, highly-regulated low-noise constant-voltage power supply for excitation of the bridge. Several switch-selected values of voltage are desirable. Occasionally accurate constant-current excitation is requested.

(3) Additional connections for remote voltage sensing so that the accurate power supply voltage is maintained at the bridge to eliminate long-line effects.

(4) Additional connections for single shunt calibration. The total number of connector terminals to the bridge can be at least 8, plus shield to accommodate the four bridge connections, remote voltage sensing and calibration connections.

(5) Provision for user - selection of the shunt calibration resistors.

(6) A means for normalizing the instrument gain with respect to the transfer ratio or sensitivity of the bridge. This allows quick calibration of the instrument in terms of the full scale value (in eu) shown on the range switch. A technique for this is indicated later in this section.

Important Specifications

Important specifications for the differential amplifier include input impedance, pump-out current, zero drift, zero stability, noise, common mode characteristics, and frequency response. These specifications are discussed in some detail in the following paragraphs:

(1) The input impedance can vary from 10^6 to 10^9 ohms typically. Generally, the higher the input impedance, the lower the pump-out current, and the better the common mode rejection (CMR) for unbalanced source impedances.

(2) The pump-out current is direct-current emanating from the input terminals. It can vary from less than 1 nanoampere (nA) to 100 nA. The pump-out current determines the amount of internal bridge balance correction necessary for unbalanced source impedances. The differential temperature coefficient of pump-out current can affect zero drift for high bridge resistances.

(3) Zero drift is an extremely important specification which is usually given in terms of voltage drift per degree temperature change with two components: one RTI and the other RTO. Sometimes the drift is specified in terms of percent of full-scale deviation per degree temperature change, but this can always be converted to the voltage specification. Typical specifications vary from:

0.1 μV/°C RTI ± 20 μV/°C RTO

for chopper stabilized amplifiers to:

10 μV/°C RTI ± 1 mV/°C RTO

for less expensive amplifiers using close thermal compensation. It is assumed that the maximum gain of most bridge conditioners is at least 1000.

(4) Zero stability gives the long-term stability of the amplifier over typically an 8 or 24 hour period, at constant ambient temperature. Typical specifications vary from:

±1 μV RTI ±100 μV RTO over 200 hours for chopper-stabilized amplifiers to:

± 40 μV RTI ± 10 mV RTO for 24 hours for less expensive amplifiers using monolithic input stages.

(5) The noise specification is usually given in at least two parts to account for the

increased spectral levels at very low frequencies. In a sense, the long-term stability specification can be considered to be a very low frequency noise specification. Typical specifications vary from:

3 μV rms for 100 kHz bandwidth and 2 μV peak-to-peak for 10 Hz bandwidth for chopper-stabilized amplifiers. (Both RTI).

5 μV rms for 10 Hz to 10 kHz band and 10 μV peak-to-peak for 0.1 to 10 Hz bandwidth for monolithic input devices (both RTI)

The component RTO varies from 1 mV to 6 mV rms depending on the upper frequency limit (usually 10 kHz to 100 kHz)

It is necessary to note that the zero stability specification must be larger than the low frequency noise specification above to be meaningful. Also, an extremely low specification of zero drift is not very useful for an instrument which does not have correspondingly good specifications for zero stability and noise. In other words, a zero drift of 0.1 $\mu V/^{o}C$ RTI would not be very useful with an instrument with 10 μV p-p low frequency noise.

(6) The specification of common-mode characteristics usually has two major parts: the rejection-ratio (CMRR) and the maximum common-mode voltage (CMV). The CMRR is usually specified at maximum gain. Typical values of CMRR vary from 80 dB to 130 dB over the frequency range from 0 to 60 Hz. The maximum common-mode voltage varies from ±10V to 350V.

The specification is necessary to insure good rejection of power frequency voltages induced in the cable connecting the bridge to the conditioner, as well as the large static operating voltages for the bridge. The common-mode voltage should be at least as large as the maximum bridge supply voltage.

Gain Normalization

An accurate internal power supply for exciting the bridge is an important feature in order to provide gain normalization. It allows the bridge sensitivity to be quickly calculated. Consider the following example.

The output voltage ΔV due to a change in resistance ΔR of a single-active-arm bridge with element resistance R and excitation voltage V can easily be shown to be:

$$\Delta V = \frac{\Delta R}{4R} V \qquad (7)$$

The gage factor and bridge sensitivity are defined in Eqs (1) and (3), which are repeated below:

$$F = (\Delta R/R)/(\Delta L/L) \qquad (1)$$

$$S = \Delta V/(\Delta L/L) \text{ mV/1000 } \mu\varepsilon \qquad (3)$$

Substitution of (7) and (1) into (3) yields:

$$S = \frac{FV}{4} \qquad (8)$$

With more than one active arm, and identical gages:

$$S = \frac{(\text{active arms})FV}{4}$$

Calculation of bridge sensitivity is extremely simple and accurate, because both F and V are known accurately.

The sensitivity normalization circuit can follow the differential input circuit in the bridge conditioner. A ten turn locking dial and a two position range switch can easily provide normalization over a 100:1 range of input sensitivities.

CONCLUSION

This paper was prepared as a prelude to the revision of ANSI Standard S2.4-1960 by subcommittee S2-64 of the ANSI Committee on Mechanical Shock and Vibration.

REFERENCES

"Specifying the Characteristics of Auxiliary Equipment for Shock and Vibration Measurements" ANSI
Standard S2.4-1960, American Standards Association, New York, N.Y. (1960)

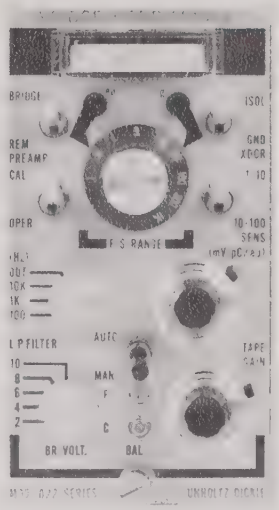
"Methods for Specifying the Characteristics of Auxiliary Equipment for Shock and Vibration Measurement"
International Electrotechnical Commission Publication 222, Geneva, Switzerland (1966).

MODEL D22PMB
BRIDGE CONDITIONER

The "Auto-Null"

A direct-coupled differential amplifier & charge amplifier, too

- MEASUREMENTS TO ZERO FREQUENCY
- AUTOMATIC BALANCING
- PRECISION BRIDGE POWER SUPPLY
- INTERNAL BRIDGE COMPLETION RESISTORS
- DIAL-A-GAIN SENSITIVITY NORMALIZATION
- EASY CALIBRATION
- SINGLE SHUNT CALIBRATION CHECK
- LOW NOISE-WIDE BANDWIDTH
- FOUR POSITION LOW-PASS FILTER
- HIGH CMRR AND CMV
- USE WITH PIEZORESISTIVE TRANSDUCERS
- REMOTE PREAMP. FOR USE WITH PIEZOELECTRIC TRANSDUCERS



The Model D22PMB helps round out the Model D22 line of instrumentation. The necessary features of direct-coupled bridge conditioners are provided plus a number of others that make the instrument easier to operate and more versatile than otherwise competitive instruments. The D22PMB is capable of operating with 1, 2 or 4 arm bridges, has provisions for internal completion networks, and contains a precision bridge power supply. The instrument and associated bridge circuit may be automatically balanced by momentarily depressing a front-panel switch. Calibration of the instrument is easily accomplished by dialing in the bridge sensitivity on the associated front panel controls. Calculation of the bridge sensitivity is made simple because of the precision voltage supply.

Remote voltage sensing and a single-shunt calibration check are standard features. The low noise characteristics are enhanced by a selection of one of four low-pass filters. Maximum bandwidth is in excess of 50 kHz. Low drift, good zero stability, and good mode rejection are provided, and high common-mode voltages are handled by a special circuit configuration, which is described below.

A front-panel switch allows remote charge or voltage preamplifiers (U-D Models 22CA-2 and 11PA-2) to be used with the Model D22PMB. In this fashion signals from capacitive transducers can be handled, thus increasing the versatility of the instrument.

SENSITIVITY NORMALIZATION AND CALIBRATION

Output normalization for transducers having widely varying sensitivities by means of a direct-reading ten-turn dial (Dial-A-Gain) has always been an important feature of U-D instrumentation. Following normalization, the maximum output voltage of the instrument corresponds to a given number of engineering units (eu) at the input, as determined by the full-scale range switch.

This feature is also provided by the D22PMB for bridge transducers, since five accurate values of excitation voltage from 2 to 10 V are supplied. As an example, for strain gage bridges measuring normal strain with identical bridge arms, the sensitivity of the bridge output in mV/1000 microstrain is easily shown to be the product of the number of active arms A, the gage factor F, and the excitation voltage V, divided by 4:

$$S = AFV/4 \qquad (mV/1000\mu\varepsilon)$$

For a sensitivity setting of 1.0 and F.S. range of 0.1, and maximum output voltage of 10, the nominal maximum gain is 10^5.

8. ZERO STABILITY (Inputs Shorted)

8.1 Temperature: ±2 µV/°C, RTI ±.5 mV/°C RTO for 1-10 SENS range. (Typically 1 µV/°C)

8.2 Time: ±10 µV RTI ±1 mV RTO for 8 hours after 30 minute warmup.

9. INPUT BALANCE

9.1 Manual: Fine and Coarse balance controls ±10 mV offset RTI

9.2 Automatic: Corrects ±10 mV offset RTI
Correction Time Constant = 50 (F.S. RANGE) (SENS DIAL SETTING) msec or 50 msec for 0.1 eu F.S. and SENS DIAL = 10 turns.

10. NOISE

The following table gives the maximum noise as a function of SENSITIVITY RANGE and FILTER POSITION from a lower frequency of .1 Hz with the input shorted. Note that the 3dB frequencies are twice the filter frequencies on the front panel.

SENS RANGE → / FILTER POSITION	1-10	10-100
100	5 µV RTI + 1 mV RTO (p-p)	20µV RTI + 1 mV RTO (p-p)
1k	1.0µV RTI + .2 mV RTO (rms)	5µV RTI + .2mV RTO (rms)
10k	2.5µV RTI + .3 mV RTO (rms)	8µV RTI + .3mV RTO (rms)
OUT	6.0µV RTI + .5 mV RTO (rms)	30µV RTI + .5mV RTO (rms)

11. COMMON MODE

11.1 Rejection of input amplifier with source unbalance of 1K, for frequency range of 0-100 Hz and full scale range of 0.1 eu
> 100 dB SENS RANGE 1-10
> 86 dB SENS RANGE 10-100
Input reference-voltage rejection (GND XDCR) > 120 dB at 60 Hz

11.2 Voltage: ±10V peak - input amplifier (ISOL XDCR)
±300V peak - reference voltage rejection - (GND XDCR)

12. CALIBRATION

12.1 Bridge: Front panel switch shunts user-selected fixed resistor across one arm of the bridge.

12.2 Remote Preamp: Front panel switch applies calibration voltage from internal/external oscillator in place of signal from remote preamp.

13. HARMONIC DISTORTION

Less than 0.5%

14. POWER

105-125V AC or 210-250V AC 50-60 Hz 10 VA

15. FRONT PANEL CONTROLS

15.1 Full Scale Range Switch (eu) 0.1; 0.3; 1; 3; 10
15.2 Sensitivity Dial (10 turn locking) 0.5-10.5 multiplier
15.3 Sensitivity Range (locking-toggle) 1-10; 10-100 mV/eu
15.4 Tape Gain (Peak Output Voltage) (10 turn locking) 0-10 V
15.5 LP Filter (4 position) 100; 1k; 10k; OUT (Hz)
15.6 Bridge Voltage (5 position) 2; 4; 6; 8; 10 V
15.7 Cal-Switch (locking toggle) Cal; Oper.
15.8 Balance (2 potentiometers) Coarse, Fine
15.9 Balance Switch (3 position) Auto Bal. (momentary); Auto Oper.; Manual Oper.
15.10 XDCR Switch (locking toggle) Isolated; Grounded
15.11 LED Full-Scale Indicators: eu; g

16. CONNECTORS

16.1 Bridge Input - DBC-9S with retainer clamps
16.2 Remote Preamp - Isolated BNC
16.3 Output - Isolated BNC

17. PHYSICAL

17.1 Module Dimensions 2.8 W x 5.25 H x 19 D
17.2 Rack Adapter (22RA) 19 W x 5.25 H x 21 D (6 modules)
17.3 Weight: 6 pounds
17.4 Operating Temperature: 40°F to 125°F
17.5 Front Panel: Amco light gray metallic
17.6 Case: Gray vinyl-covered aluminum

UNHOLTZ-DICKIE CORPORATION
3000 Whitney Avenue, Hamden, Connecticut 06518
Area Code (203) 288-3358

Bulletin D22PMB-74
Printed in U.S.A.

The "Basic"

MODEL D22PM
CHARGE AMPLIFIER

A General-Purpose Laboratory Instrument

- EXTREMELY LOW-NOISE OPERATION
- DIAL-A-GAIN SENSITIVITY NORMALIZATION
- CALIBRATED FULL-SCALE OUTPUT
- OPERATION WITH REMOTE PREAMPLIFIERS
- DIFFERENTIAL REJECTION OF GROUND SIGNALS
- PLUG-IN 3-POLE FILTER
- LOW POWER CONSUMPTION
- THREE CALIBRATION MODES
- INSENSITIVE TO EXTERNAL VIBRATION
- INDIVIDUAL SHIELDED POWER SUPPLIES
- WIDE VARIETY OF OPTIONS

The Model D22PM is the successor to the Model D11 line of instruments. The D22PM features plug-in card construction, extensive use of integrated circuits and rugged construction. Independent power supplies and shielded transformers are used so that individual operation is possible, grounding problems are minimized in large installations, and good power line isolation is provided.

In addition, separable references are provided for the input and output circuits so that an internal differential circuit can remove common-mode ground voltages caused by having the transducer case grounded at the point of measurement.

The Dial-A-Gain sensitivity normalization, originated by Unholtz-Dickie, allows the various outputs to be normalized for piezoelectric transducer sensitivities ranging from 0.5 to 100 pC/unit.

Being a charge amplifier, the gain of the D22PM is, of course, insensitive to input cable length.

NOISE

Extremely low output noise has been attained by careful selection of the input FET for the charge converter. Careful shielding, highly regulated power supplies and balanced circuitry keeps power frequency contamination extremely small. The built-in 3-pole low-pass filter can be selected to optimize the signal-to-noise ratio by proper knowledge of the expected signal spectrum.

Using the D22PM and the U-D Model 75D21 Accelerometer, with a relatively short low-noise cable, it is possible to achieve a typical noise level of 50 x 10^{-6}g rms over a 10 kHz frequency range. This means that acceleration levels less than .001 g may be accurately measured.

OUTPUTS

The standard tape output is calibrated to give exactly 10 V peak for full scale inputs for full clockwise rotation (10 turns) of the TAPE GAIN potentiometer. The locking dial accurately determines full scale output for other settings. The 1.24 inch scale edge-reading meter is calibrated in percent of full scale. Options include servo control (S) at 10 mV/g, a high-current driver for long lines or galvanometers (C or G), linear DC output (F), and logarithmic DC output (L).

RANGES

The maximum instrument gain, for a full scale range setting of 1 g and an input sensitivity of 1 pC/g, is 10 V/pC. Standard manual ranging provides seven full scale ranges from 1 to 1000 g in 1, 3, 10 steps, for input sensitivities from 1 to 100 pC/g.

The high gain option (-3) gives a maximum gain of 100 V/pC and nine ranges from 0.1 to 1000 g in 1, 3, 10 steps.

The external range control (E) and automatic-ranging (A) options described extensively in another bulletin provide four full-scale ranges: 1, 10, 100, and 1000 g. Two-line range control is possible for the E option and the best range is automatically selected for the A option. The E option also allows manual range control and the A option includes all the E option features.

FILTERS

A three-pole low-pass Butterworth filter is contained on a sub-plug-in board within the instrument. The instrument may be operated with the filter plug-in removed if desired. Other filter frequencies are easily and economically supplied.

CALIBRATION

The D22PM provides three calibration/checking Modes: F-CAL, V-CAL, and TEST. The F-CAL mode provides full scale output for 100 mV peak input regardless of range and sensitivity settings. The V-CAL mode provides an output dependent on all front-panel settings. The TEST mode inserts the calibration signal in series with the accelerometer cable shield. An open or shorted line is easily detected.

REMOTE PREAMPLIFIER

Remote voltage preamplifiers or charge preamplifiers such as the U-D Model 11PA-2 or Model 22CA-2, are accommodated by changing a front panel switch from INT. to REM. This allows the internal charge converter to be bypassed and means that standard low-cost coaxial cable may be used between the measurement site and the instrument. Triboelectric noise for long-line measurement is also avoided.

SPECIFICATIONS MODEL D22PM

1. GENERAL

1.1 Separate, isolated power supplies are provided in each channel

1.2 All power and signal connections are made at separate rear mounted connectors.

1.3 Each channel is totally enclosed so that it can be used with equal convenience as a bench mounted or as a rack mounted instrument.

2. INPUT CHARACTERISTICS

2.1 Charge input - direct connection to any piezoelectric transducer with 10 Megohms, or greater, shunt resistance.

2.2 Remote Preamp Input - two-wire connection to remote charge type or voltage type preamp that can be added to the system at anytime. The Preamp connector supplies the required bias voltage/current to the remote preamp.

2.3 Gain Change with Source Capacitance in Charge Mode (INT.) - A source capacitance of 50,000 pF shall cause less than 0.1% gain change for transducers having a sensitivity between 1 and 100 pC/unit.

2.4 Gain Change with Remote Preamp Mode (REM. PRE-AMP) - all instrument gain controls and range switches shall apply when operation is converted to the remote preamp mode. The basic instrument accuracy shall change by less than ±1%. Up to 2,000 feet of RG58/U coaxial cable shall cause a gain change of less than 1% when connected between the instrument and the remote preamp.

2.5 Maximum Input in Charge Mode (INT.)

±15,000 pC (1 to 10 pC/g.) ±150,000 pC (10 to 100 pC/g.)

3. OUTPUT

3.1 Tape Driver - Calibrated ±10 V peak at full scale condition into 1 K load. Ten turn locking potentiometer allows precision adjustment between 0 to 10 V. Output impedance less than 50 ohms direct-coupled.

3.2 Standard Meter - 1.24 inch scale meter calibrated in percent of full scale. Accuracy ±2% of full scale; average detector provided. Dual scale is available upon request.

3.3 Large Meter (Option "-8") - 2.5 inch scale length with 2 scales calibrated 0 - 10 and 0 - 3. Increases front panel height to 8-3/4 inches.

3.4 Servo Control (Option "S") - Output normalized to 10 mV pk/g pk, not dependent upon range switch position. No signal clipping occurs at the servo output at levels less than 100 g on any full scale range, and operates to 1000 g without clipping when placed on that range.

3.5 Galvanometer Driver (Option "G") - A high current amplifier provides a separate independent output with a current capacity of ±100 mA. Ten turn locking potentiometer allows precision adjustments between 0 and 10 V. Output impedance less than 1 ohm direct-coupled.

3.6 Log DC Output (Option L) - A DC output proportional to the logarithm of the input amplitude. The calibration constant is +1.0 V/decade and an output of 0 V DC is provided at full scale.

3.7 Velocity Integrator (Option I) - Output normalized to 100 ±10 mV-sec/in, not dependent on range switch position.

4. FREQUENCY RESPONSE

4.1 Low Pass Filter "Plug-In" Removed

±1% 10 Hz to 10 kHz ±5% 2 Hz to 30 kHz

4.2 Low Pass Filter "Plug-in" Installed - Plug-in component card supplied with unit is 3 pole maximally-flat Butterworth design. Filter frequency f_o can be supplied in 1, 2, 5, 10 sequence from 50 Hz to 10 kHz. Response at f_o is rated ±2% and at 2 f_o is -3 dB ±1 dB, with 18 dB/oct. attenuation rate.

5. RANGE SWITCHING

5.1 Standard - 1 to 1 K g full scale in 1-3-10 sequence for 1-100 pC/unit.

5.2 Option 3 - .1 to 1 K g full scale for 1-100 pC/unit in 1-3-10 sequence.

5.3 Option E - 1, 10, 100, 1000 g full scale controlled by front panel switch or by external 2-line binary control compatible with TTL logic. Logic 1 can be as high as +15 V.

6. MAXIMUM NOISE (RTI-referred to input; RTO-referred to output) All statements refer to 10 kHz low-pass filter, and 10 Megohm input resistance or greater.

6.1 Standard Range Option - .005 pC rms plus .0015 pC rms/1000 pF source capacitance RTI for 1-10 pC/unit and .05 pC rms plus .0015 pC rms/1000 pF source capacitance for 10-100 pC/unit RTI plus 1 mV rms RTO.

6.2 Range Option 3 - .005 pC rms plus .0015 pC rms/1000 pF source capacitance RTI for 1-10 pC/unit and .05 pC rms plus .0015 pC rms/1000 pF RTI for 10-100 pC/unit. plus 5 mV rms RTO.

7. CALIBRATION MODES

7.1 F-CAL - provides full-scale output for 100 mV peak input independent of full scale range or sensitivity setting.

7.2 V-CAL - connects calibration signal through precision 1000 pF ±½% capacitor directly to charge amplifier input providing 1 pC/mV conversion.

7.3 TEST - connects calibration signal in series with shield of input cable.

7.4 OPER - calibration signal disconnected for normal operation.

7.5 Internal Oscillator (Option O) - provides calibration signal of 100 mV peak ±1% at 100 Hz. One oscillator can supply a total of six channels with patch cables supplied.

8. GROUND SIGNAL REJECTION - This input ground/output ground isolation feature allows the transducer case to be grounded at the test site without introduction of output due to ground loops.

8.1 The output voltages normally created by ground loops due to grounded transducer cases are rejected by at least 60 dB at maximum instrument gain from 5 Hz to 1 kHz.

8.2 The front panel range switch lamp verifies the correct position of the ISOL-GND front panel switch.

9. HARMONIC DISTORTION less than 0.5% and amplitude linearity is ±1% of best straight line.

10. POWER - Individual power supplies in each module; double-shielded power transformer;
100-130 V AC or 200/260 V AC; 50/60 Hz; 5 VA consumption

11. FRONT PANEL CONTROLS

11.1 Full Scale Range Switch

11.2 Mode Switch-Test; V-Cal; Oper; F-Cal

11.3 Sensitivity Dial (10 Turn locking)

11.4 Sensitivity Range Switch 1-10, 10-100

11.5 Case Switch - Isol; Gnd. (Range Pilot)

11.6 Preamplifier Switch - Remote; Internal

11.7 Tape Gain Dial (10-turn locking)

12. PHYSICAL

12.1 Single Module Standard - 2.8 W x 5.25 H x 19 D - requires Model 22RA Rack Adapter for multichannel mounting of up to six channels.

Rack Adapter 22R: 19 W x 5.25 H x 21 D (6 modules)

12.2 Single Module "-8" Option - 2.8 W x 8.75 H x 19 D - requires Model 22RA-8 Rack Adapter for multichannel mounting of up to six channels.

12.3 Connectors are all coaxial BNC except for:
Oscillator-Patch-miniature phone jacks - mating connector supplied

12.4 Weight: Single module - nominal 6 pounds

12.5 Operating Temperature: 40°F to 125°F

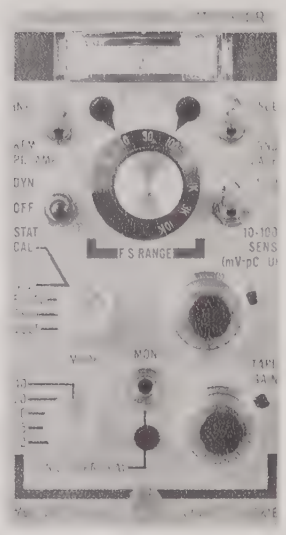
UNHOLTZ-DICKIE CORPORATION
2994 Whitney Avenue, Hamden, Connecticut, 06518
Area Code (203) 288-3358

MODEL D22 SERIES
SIGNAL CONDITIONING AMPLIFIERS

Three versatile amplifiers with ~~7~~ ~~10~~ many options

MODEL D22PM "BASIC"

MODEL D22PMH "RED-HOT"



MODEL D22PMR "MULTI"

A complete redesign and expansion of the signal conditioning line has resulted in amplifiers which satisfy three wide application areas. The D22PM, "Basic", is a charge amplifier which satisfies most standard laboratory needs. The D22PMH, "Red-Hot", is a high-performance charge-amplifier for use with high-temperature (differential) accelerometers. The D22PMR, "MULTI", operates in a charge or voltage mode with piezoelectric devices and in a voltage mode with strain-gage transducers. The circuit design makes extensive use of integrated circuits and plug-in circuit cards, which allow great versatility for adding options. Rugged modular construction allows separate operation or six units to a rack adapter in high noise environments.

COMMON FEATURES OF ALL THREE AMPLIFIERS INCLUDE:

- o Individual shielded power supplies
- o Extreme low-noise operation
- o Wide frequency range 2 Hz - 100 kHz
- o U-D originated DIAL-A-GAIN calibrated sensitivity normalization
- o Calibrated full-scale tape output
- o Differential rejection of ground loop signals
- o Operation with remote preamplifiers
- o Reduced heat load - typically 5 VA
- o Plug-in 3-pole low-pass filters
- o Several Calibration Modes

THE INDIVIDUAL AMPLIFIERS ADD THESE FEATURES:

"BASIC" D22PM

- o Low Cost
- o Guarded Charge Converter
- o Three Calibration Modes
- o Gain insensitive to cable capacitance
- o Options for driving long lines, providing transmissibility plots, controlling servos

"RED-HOT" D22PMH

- o Accommodates single-ended or differential accelerometers
- o Guaranteed noise performance for 50k input shunt resistance
- o Operable to 10k shunt resistance
- o Switchable 3-pole hi-pass and low-pass filters
- o Meter indication

"MULTI" D22PMR

- o Charge or voltage mode
- o Strain gages or piezoelectric devices
- o Simple sensitivity normalization for strain gages
- o Constant-current source for strain gages
- o Internal square-wave gage calibration check

The following table summarizes the outstanding features and helps user selection of options such as meters, log DC output, external range control, and autoranging. The Models D22PMS, D22PMGS, D22PMGSLTO, D22PMHS, and D22PMRS are normally factory stocked for short delivery. Other models are built to order and normally require a minimum order of six units.

LEGEND: S - Standard O* - Option Factory Stocked Z - Consult Factory For Availability
O - Available Option N - Not Available

FEATURE/OPTION	OPTION LETTER/ NUMBER	"BASIC" D22PM	"RED-HOT" D22PMH	"MULTI" D22PMR	COMMENTS
Ground Loop Signal Rejection	D	S	S	S	
Internal/Remote Preamp	P	S	S	S	
Meter-Edge Reading ±2% F.S.	M	S	S	S	
1-10, 10-100 Sens. Ranges	-	S	S	S	
10 Turn Locking Sens. Pot	-	S	S	S	U-D Dial-A-Gain
10 Turn Tape Gain ±10V F.S.	-	S	S	S*	*±1V F.S.
Fixed Plug-In LP Filter	-	S	N	S	3-Pole Butterworth
In/Out Switch LP Filter	-	N	S	N	6 & 10 Pole Also Available
In/Out Switch HP Filter	-	N	S	N	6 & 10 Pole Also Available
Test, F-Cal, V-Cal Modes	-	S	S	N	
Diff. Accel. (Hi-Temp) Input	H	N	S	N	Includes K
Single Ended Hi-Temp Input	K	O*	S	O*	
Strain Gage, Charge, Volt Input	R	N	N	S	
10 mV/g Servo Output	S	O*	O*	O*	
100 mV-sec/in. Vel. Output	I	O	O	O	Requires S
1 V/in. DA Disp. Output	II	O	O	O	Requires S & I
Linear DC Output	F	O	O	O	
Log DC (1V/20dB) Output	L	O	O	O	Requires M
Manual Ranging 1-3-10 F.S.	-	S	S	S	
Remote Range Control (2 line)	E	O	O	O	4 Decade Ranges
Automatic Range Selection	A	O	Z	Z	Includes E, Requires M
High Current Line Driver ±100 mA	C	O	O	O	Current Booster For Tape Out
Independent Galvo Output ±100 mA	G	O*	N	N	Adjustable with 10T Pot.
Calibration Oscillator	O	O	O	O	100 mV pk at 100 Hz
Tracking Filter	T	O	O	O	Allows internal insertion
Freq Resp ±5% 2Hz to 30 kHz	-	S	S	S	
Extended Low Freq. ±5% 0.5 Hz	-2	O	O	O	
Extra X 10 Gain	-3	O	O	N	.01 g F.S. For 10-100 Sens
Full-Scale Relay Calibration	-4	O	O	O	
Large 2½" Scale Meter	-8	O	Z	Z	8.75 In. Panel Height

UNHOLTZ-DICKIE CORPORATION

2994 Whitney Avenue, Hamden, Connecticut, 06518

VIBRATION TEST EQUIPMENT

- VIBRATION TEST SYSTEMS
- VIBRATION TRANSDUCER CALIBRATION SYSTEMS
- RANDOM ACCESSORIES
- COMBINED SLIP TABLE ASSEMBLIES
- AUTOMATIC SINE CONTROLS
- LOW COST TRACKING FILTERS
- SIGNAL CONDITIONING AMPLIFIERS
- ACCELEROMETERS

manufacturers of shaker systems, advanced instruments and accelerometers

UNHOLTZ-DICKIE CORPORATION

3000 WHITNEY AVE. / HAMDEN, CONN. 06518 / (203) 288-3368

INTRODUCTION

Vibration testing has been a major tool used in the development of military and space hardware for over 25 years. Today, the benefits of vibration testing are being applied in a variety of commercial and consumer product areas as well. This trend parallels an increasing number of federal regulations which require more comprehensive testing to assure product reliability and safety.

Vibration testing can genuinely benefit the manufacturer. By simulating environmental vibration levels during actual product development, the engineer can verify that a design is suitable for its application. This type of testing establishes performance and reliability prior to release of a design for production. Such an approach can save money by minimizing the probability of major redesign work, and even legal liabilities which may result from an inadequate product design. In addition, quality control procedures can be enhanced by using vibration testing as a tool to monitor the consistency of production methods and materials.

Electrodynamic shaker systems are used in a variety of test applications. A typical arrangement for automatic sine testing is shown in FIG. 1. Such a setup provides automatic frequency cycling at preselected vibration levels, under servo control. A typical test "program" is shown in FIG. 2.

Figure 1. **SETUP FOR AUTOMATIC SINE TESTING**

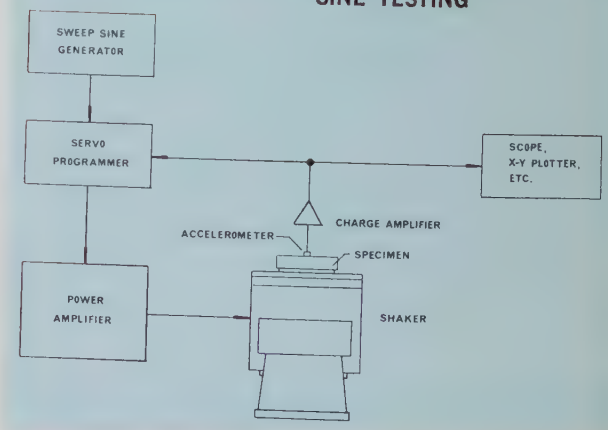
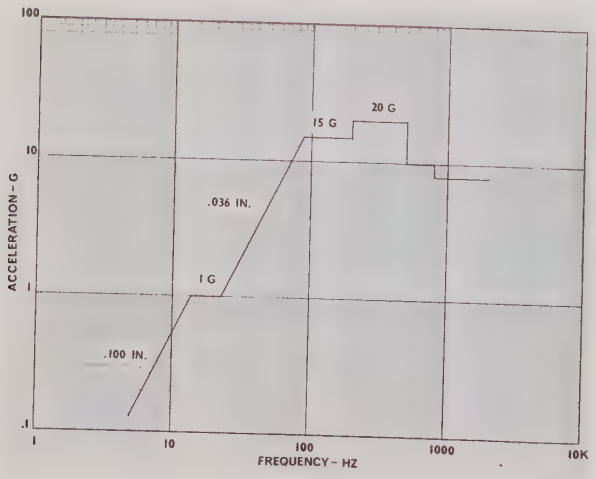


Figure 2. **EXAMPLE OF TEST PROGRAM**



The block diagram above could represent any of a wide variety of available vibration test systems. Unholtz-Dickie, the industry leader in solid state powered shaker systems, offers a complete line of vibration test systems as well as a full complement of signal conditioning and control instrumentation. See page 3 for a convenient listing of Unholtz-Dickie shaker systems. The remaining pages describe many of the instruments and system accessories that have helped make Unholtz-Dickie today's number one manufacturer of vibration test equipment.

The purpose of this short form catalog is to summarize the standard vibration test equipment manufactured by the Unholtz-Dickie Corporation. Detailed information on the many systems and related accessories is available on request.

VIBRATION TEST SYSTEMS

Unholtz-Dickie produces vibration test systems for all test applications. Sine force ratings range from 50 to 20,000 pounds. The table below lists these systems, with pertinent technical data. Special systems, including those with multiple shakers are also available.

Every Unholtz-Dickie system includes a safe, reliable, proven solid state power amplifier, and features reliable air cooling of the shaker armature. Systems engineering of each system element assures maximum performance and utilization, with simplified operation.

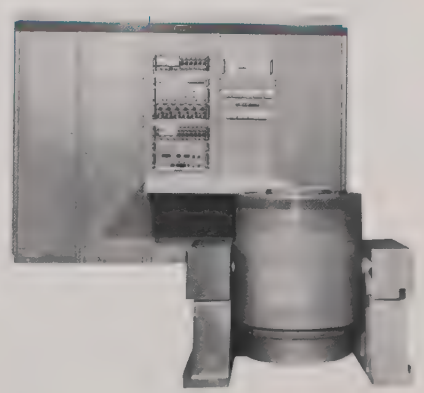
SYSTEM PERFORMANCE				SHAKER	
FORCE (lbs)		STROKE (inches, DA)	MAX. SINE PAYLOAD (lbs) at 20g	ARMATURE WEIGHT (lbs)	TABLE DIA (inches)
Sine (pk)	Random (rms)				
50	—	0.5	1.8	0.69	2
50	—	1.0	1.9	0.55	drive rod
150	—	4.0	5.2	2.25	drive rod
250	125	1.5	9.7	2.75	3.5
300	180	1.5	12.2	2.75	3.5
500	300	1.0	19.7	5.3	4.5
1,000	—	6.0	39	11	drive rod
1,200	600	1.0	46	14	5.75
1,200	600	1.0	40	20	8
1,700	850	1.0	65	20	8
3,000	2,200	1.0	134	16	5.75
3,000	2,200	1.0	128	22	8
3,800	2,200	1.0	162	28	8
6,000	3,000	1.0	264	36	12
6,000	4,500	1.0	264	36	12
8,000	4,000	1.0	310	90	16
12,000	6,000	1.0	510	90	16
12,000	8,000	1.0	505	100	16
17,500	12,000	1.0	780	95	16
17,500	15,000	1.0	780	95	16
19,500	14,000	1.0	880	95	16
20,000	18,000	1.0	905	95	16

INDUCT-A-RING

The Unholtz-Dickie INDUCT-A-RING Shaker features a solid metal, single turn armature coil for maximum reliability in a high performance machine. AC currents are induced into the metal ring, eliminating the need for current connections to the armature. This exclusive air cooled armature provides unmatched ruggedness and service life. INDUCT-A-RING Shakers are available in 12,000 pound force systems and up.

SOLID STATE POWER

Unholtz Dickie pioneered the use of solid state power amplifiers for driving electrodynamic shakers. The present design has demonstrated reliable performance since early 1968. No power transistors since introduced on the market offer the promise of better performance and reliability. Today, amplifiers with output ratings to 200 kVA are offered. Direct coupling to the shaker provides superior low frequency performance, such as 1 inch peak-to-peak displacement at 2 Hz, as required by some MIL-STD-810B procedures.



19,500 pound system with 120 kVA solid state power amplifier and INDUCT-A-RING Shaker, shown with optional instrumentation.

SERIES 300
VIBRATION TRANSDUCER
CALIBRATION SYSTEMS

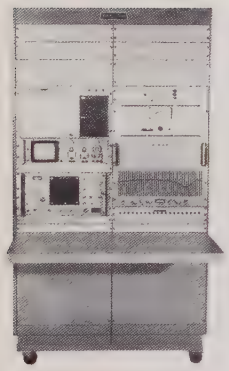
The Series 300 Calibration Systems are offered with manual controls for point by point calibration, or with frequency sweeping controls giving an automatically drawn curve of % deviation of the "unknown" transducer sensitivity relative to the "reference" accelerometer, as a function of frequency. Original data is permanently plotted, eliminating operator errors in readout and transcription.

At full system performance, and with automatic servo controls operating, acceleration waveform distortion is less than 1.5% at all operating frequencies. The overall system noise level is less than .005 g rms. Automatic plotting systems feature 0.25% plotting resolution of the unknown transducer output relative to the reference.

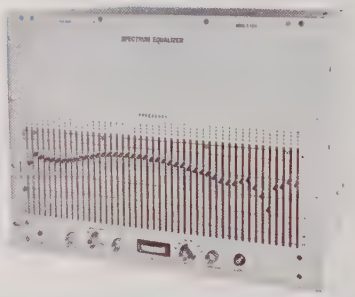
Model 351

Automatic Recording Vibration Calibration System with Optional VI100 Shaker Vibration Isolation

RANDOM ACCESSORIES



Complete random testing capability is available with systems-engineered random controls. A typical remote random control console configuration is shown here.



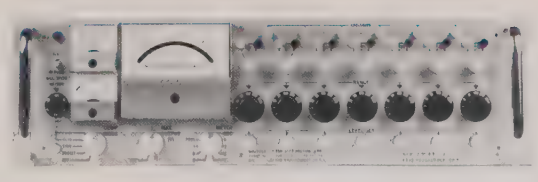
Random Accessories include the Model E109B Spectrum Equalizer, featuring 45 active filters with individual, rectilinear motion attenuation controls. Convenient equalization can be performed using this unit in conjunction with a real time analyzer.

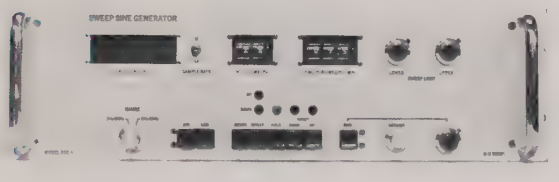
PERMALINE
COMBINED SLIP TABLE ASSEMBLIES

The PERMALINE Combined Slip Table Assembly provides for testing in three axes while using only one fixture. Permanent factory alignment of the shaker and slip plate allows quick change from vertical to horizontal operation. In addition, no special floor construction is required since inflatable air mounts effectively isolate the entire assembly from the supporting structure.

AUTOMATIC SINE CONTROLS

Model SP-7 Servo Programmer features amplitude servo, vibration meter, seven segment programmer, and optional charge amplifier for automatic, multi-level sine testing. All controls are interlocked to prevent damage to the test specimen. Model SP-2 Servo Programmer features two segment programmer.



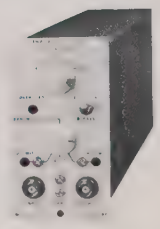


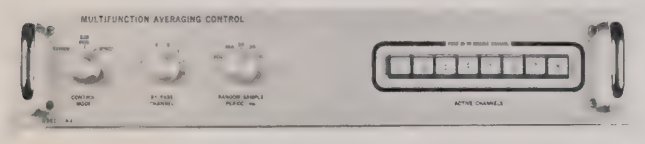
Model OSC-1 Sweep Sine Generator is systems engineered to provide the vibration test system input sine wave signal for continuous cycling over a 3-decade frequency range. Unit features digital counter frequency display that can count and display ten times per second regardless of the operating frequency.

SPECIAL CONTROLS

Model AM-122 Acceleration Monitor and Limiter offers independent vibration system overtest protection in the event of equipment failure or misoperation of the system control channel. Shutdown is obtained by use of an adjustable meter relay and solid state signal conditioning circuitry.

Model TF11 Tracking Filter features a constant 10 percent bandwidth between the limits of 2 and 200 Hz, plus a standard log DC output for X-Y plotting. All this in a compact unit, at an attractive price.





Model MAC-8 Multifunction Averaging Control features eight individually selectable data channels for control to the average signal level. Can be used for sine or random vibration testing.

Model RD-1 Resonant Dwell Control automatically maintains the vibration testing frequency at the resonant frequency of a test specimen during endurance testing.

Model ACS-6 Acceleration Control Selector automatically switches to the highest (or lowest) acceleration input. Accepts six sine acceleration signals, and gates to the output whichever signal reaches its preset limit.

SIGNAL CONDITIONING AMPLIFIERS

D22 SERIES

The D22 Series provides charge amp signal conditioning for all piezoelectric transducers. Some models also provide for strain gage operation. This series features all integrated circuit design with superior low noise characteristics, in a rugged modular construction. The basic Model D22PM includes the capability of operating with a remote preamp, and includes a meter. This and other standard models are shown below. The wide range of optional features available for addition to most models, is listed below.

D22PMH | D22PM

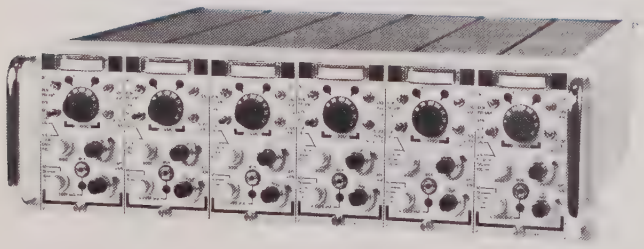
D22PMG | D22PMA

D22 OPTIONS

Description	Suffix
STRAIN GAGE OPERATION	R
HIGH TEMP ACCEL. INPUT	H
BRIDGE CONDITIONER	B
10 mV/g SERVO OUTPUT	S
100 mV-SEC/IN. VEL. OUTPUT	I
1 V/IN. DA DISP. OUTPUT	II
LINEAR DC OUTPUT	F
LOG DC OUTPUT	L
REMOTE RANGE CONTROL	E
AUTORANGING	A
±100 mA LINE DRIVER	C
±100 mA GALVO OUTPUT	G
CALIBRATION OSCILLATOR	0
TRACKING FILTER CONNECTION	T
0.5 HZ FREQ. RESPONSE	–2
EXTRA X10 GAIN	–3
FS RELAY CALIBRATION	–4
LARGE 2½" SCALE METER	–8

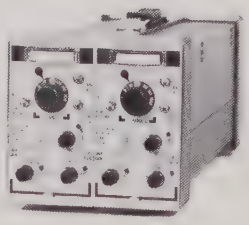
D22PMR | D22PMB

D22PMGA | P22MS



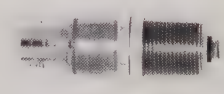
22RA

The Model 22RA Rack Adapter accepts six 22 Series modules in the standard 5¼ inch panel height. Also accepts the Model TF11 Tracking Filter (see page 5).



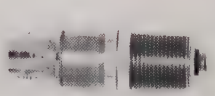
22P2

The Model 22P2 Dual Channel Portable Adapter accepts two channels of 22 Series instruments.



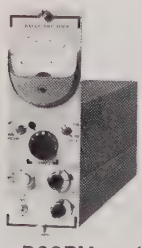
11PA-2

The Model 11PA-2 is a two-wire Remote Voltage Preamp designed for use with any of the 22 Series instruments.



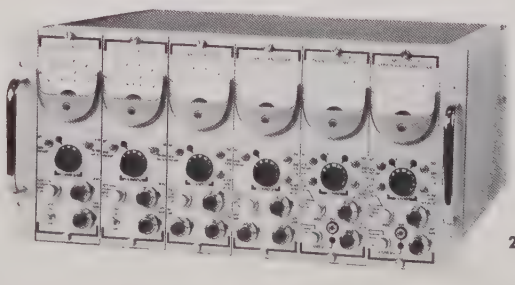
22CA-2

The Model 22CA-2 Remote Charge Preamp may be used with any of the 22 Series instruments shown above, and is a companion unit to the Model P22MS. Optional Model 22CA-2T is available for operation to 160°F.



D22PM-8

Models D22PM and D22PMR are available with the "–8" option, which provides a 2½ inch meter scale for easier readout.



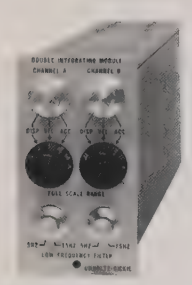
22RA-8

Rack mounted D22's with the "–8" large meter option require the 22RA-8 Rack Adapter with 8¾ inch panel height. Each 19 inch adaptor accepts six "–8" modules.

SIGNAL CONDITIONING PRODUCTS

Model SA22 Shock Charge Amplifier measures shock pulse durations from 100 microseconds to 500 milliseconds and pulse amplitudes up to 100,000 pC peak.

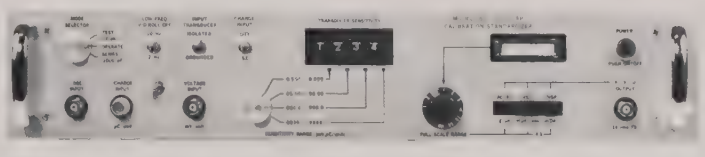
Model SA22TPM Portable Shock Charge Amplifier provides the same shock pulse measurement capability as the SA22, but also features a Transient Peak Meter for retaining peak g readings.



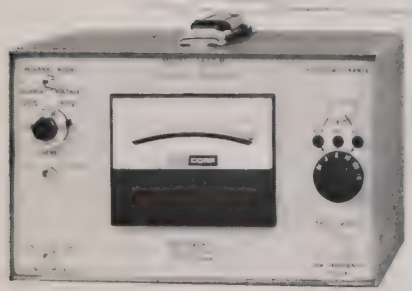
Model AVD-22M provides two channel, double integration of conditioned 10 mV/g acceleration signals. Each channel has tape and X-Y plotter outputs, plus normalized velocity and displacement outputs. Unit features 80 dB dynamic range and switchable low frequency filtering.

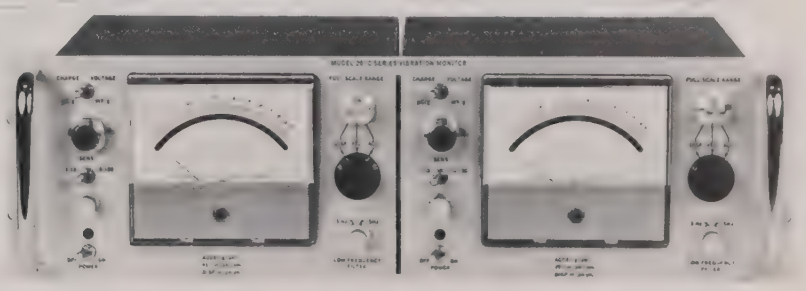
Model CV22PM-LF1 charge/voltage amplifier, operates down to 0.1 Hz. Combines capabilities for low level, low frequency vibration measurements and long duration shock pulse measurements.

Model LDC-22 provides two channel conversion to log DC of conditioned 1V peak full scale input signals for X-Y plotting. Features 5-10,000 Hz frequency response, 60 dB dynamic range, and selectable damping.



Model 1611 Precision Charge/Voltage Calibration Standardizer features typical ¼ percent overall instrument accuracy and stability. Frequency response from 2 Hz to 20,000 Hz. Used in transducer calibration systems, or wherever maximum accuracy is required.





Model 1610 Series Double Integrating Charge/Voltage Monitors are available in three standard models: 1610M (single channel, portable) 1610RM (single channel, rack mounted), and 2610 (dual channel, rack mounted). Switch selectable outputs for acceleraton, velocity, or displacement are provided along with log scale meter readout. Log DC and variable gain galvo outputs are optionally available.

ACCELEROMETERS

Unholtz-Dickie produces a full line of piezoelectric accelerometers for general purpose vibration testing and for special applications. Various models are optimized to provide features such as subminiature size, high sensitivity, high frequency operation, and normalized 10 pC/g sensitivity.

MODEL	PERFORMANCE FEATURES	NOMINAL: OPEN-CIRCUIT VOLTAGE SENS. mV-pk/g-pk	NOMINAL: CHARGE SENSITIVITY pC-pk/g-pk	NOMINAL: USEFUL FREQUENCY RANGE-Hz	NOMINAL: SIZE-INCHES WEIGHT-GRAMS	DESIGN FEATURES
2E3	**Subminiature, extremely small,** lightweight, for highest frequencies and minimum added mass. Relatively large voltage and charge outputs. Low base strain sensitivity construction.	2.5	1.0	1.0 TO 12000	HT .310 DIA .220 WT 1.22	Shear, side connector, integral cable, molded neoprene strain relief boot, adhesive mount, lead zirconate-titanate crystal. 2E5 has wrenching flats for easy removal.
2E5					HT .310 DIA .280 WT 1.36	
2D21	**Subminiature, lightweight,** with low base strain sensitivity construction. Removable cable.	3.0			HT .415 HEX .280 WT 1.31	Shear, top connector, wrenching flats for easy removal, lead zirconate-titanate crystal.
5D21-8	**Miniature, general purpose,** moderately high resonance, low base strain sensitivity, recommended for charge use.	5.0	8.0	0.2 TO 7000	HT .64 DIA .50 WT 10.7	Shear, top connector, 10-32 mounting hole, lead zirconate-titanate crystal. Stainless steel case.
10DQ21	**General purpose,** side connector for restricted height applications. Low base strain sensitivity.	20	40	0.2 TO 6000	HT .71 HEX .62 WT 25	Shear, side connector, 10-32 mounting hole, lead zirconate-titanate crystal. Stainless steel case.
75D21	**Maximum voltage and charge sensitivity** gives best signal/noise ratio for low level measurements. Low base strain sensitivity.	75	82	0.3 TO 4000	HT .74 HEX .75 WT 37	Shear, top connector, 10-32 mounting hole, lead zirconate-titanate crystal. Stainless steel case.
10B10	**Charge sensitivity normalized** at 10 pC/g. Wide temperature range, −300°F to +500°F. Flat voltage and charge sensitivities. Low base strain sensitivity.	3.1	Set at exactly 10.0	1.0 TO 4000	HT .78 HEX .62 WT 27	Double base, compression, side connector, 10-32 mounting hole. Bismuth strontium titanate crystal. Stainless steel case.
10B10T					HT .81 HEX .62 WT 29.5	Same as 10B10 but with top connector.
A-1 Probe	**General purpose** hand-held accelerometer for vibration survey.	3.5	5.2	0.3 To 600 (hand-held)	LGH 5.25 DIA .62	Shear mode, hand-held, aluminum case with stainless steel tip.
1000 PA	**High sensitivity, low noise,** and low output impedance permit very low level measurements at low frequencies. Excellent signal/noise ratio is maintained even with long runs of low cost cable.	1000	NA	0.1 TO 2000	LGH 1.0 WD 1.0 HT 2.06 WT 110	Shear mode, with integral electronics and 4-pin side connector. 10-32 mounting hole or optional magnetic base. Sealed aluminum case.
100 PA		100				

manufacturers of shaker systems, advanced instruments and accelerometers

UNHOLTZ-DICKIE CORPORATION

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WARRANTY

All products are warranted to be free of defects in material and workmanship for a period of one year from date of shipment. If the product is not installed, maintained and used in a normal manner in accordance with instructions and manuals, this warranty will not apply. Commercially available instruments and accessory items purchased and installed in the product will carry the original manufacturer's warranty.

This warranty is limited to repairing or replacing parts which have been returned and in our opinion are defective. Service required to correct defects in material or workmanship will be supplied without charges. The Buyer will pay all transportation and taxes incurred. This warranty does not cover any costs incurred by the Buyer as a result of purchase of UNHOLTZ-DICKIE CORP. equipment or any charges for the Buyer's labor for replacement, adjustment or repair unless authorized in advance in writing. We are not liable for consequential damages.

This warranty will not apply to any products which, in the opinion of UNHOLTZ-DICKIE CORP., have been subject to accident, misuse or neglect; altered or repaired with a substitute which might impair the product; or used outside of rated conditions. UNHOLTZ-DICKIE CORP. reserves the right to make improvements in its products including changes and additions without incurring obligations to incorporate such improvements in previous units.

This warranty is expressly in lieu of any and all other warranties or commitments, expressed or implied and any other obligations to the Buyer associated with the use of UNHOLTZ-DICKIE CORP. products.

4/1/73

UNHOLTZ-DICKIE CORPORATION

Incoming Instrument Inspection and Return Shipping Instructions

1. Unpacking and Inspection

If the shipping carton is damaged, note on acceptance that it is received damaged and subject to claim when inspected. Ask that the carrier's agent be present when the instrument is unpacked and inspected for damage (scratches, dents, broken knobs, etc.). If the instrument is damaged or fails to meet specifications, notify the carrier and the Unholtz-Dickie Corporation immediately. Retain the shipping carton and the padding material for possible return for repair or further inspection by carrier. The purchaser and Unholtz-Dickie Corporation will arrange for the replacement and/or repair of the damaged item.

Refer to our separate warranty page for a statement of our warranty policy.

2. Return Shipment

Return shipment procedure: Please be sure the following instructions are observed if a Model 22 Series instrument is being shipped back to Unholtz-Dickie for repair, replacement, or upon completion of use as a demonstrator or loaner.

2.1 Size of Box and Packing Instructions

2.1.1 Single Channel with 5¼ inch Panel Height

If the single channel was shipped from Unholtz-Dickie as an individual unit, replace the instrument in its original container. If the instrument was shipped as part of a rack mounted combination of channels, the single channel can be returned separately in a container that is no smaller than 22½ inch x 10½ inch x 9½ inch. The front and rear panels must be completely protected by approximately 2 inches of cushioning material. The top, bottom and sides must be surrounded by cushioning and filler materials. A strong, double wall type corrugated box, (350 lb/sq. in. minimum bursting test) has been proven to give adequate service. DO NOT USE A SMALLER OR WEAKER CONTAINER THAN THAT RECOMMENDED ABOVE.

Cover the painted surfaces of the instrument with protective wrapping paper or a plastic bag whenever the packing material might be coarse enough to scratch the painted surfaces.

2.1.2 Six Channel Rack with 5¼ inch Panel Height

CAUTION: Do not rest the rack type instrument in a vertical position with its weight on the rear since the connectors and switches at the rear of the instrument might be damaged.

Replace this instrument in the original container. Replace all packing pads and fillers in the exact position which they originally occupied. If the original container is no longer available, use a container that is no smaller than 27 inch x 20½ inch x 10½ inch.

It is important that protection be provided for the rear connectors and switches during shipment. A sheet of stiff cardboard should be placed under the instrument and then folded up to meet the top of the rear panel. The instrument should be bagged and surrounded on all surfaces by cushioning and filler materials. A strong, double wall type corrugated box (350 lb/sq. in. minimum bursting test) has been proven to give adequate service. DO NOT USE A SMALLER OR WEAKER CONTAINER THAN THAT RECOMMENDED ABOVE.

2.1.3 Single Channel with 8-3/4 inch Panel Height

Follow the instructions given in paragraph 2.1.1, except that extra precautions must be taken to prevent the front panel extension with its meter from being bent during shipment. The extended meter must be braced between packing material so that the load force will be distributed evenly over the entire front panel of the instrument.

2.1.4 Six Channel Rack with 8-3/4 inch Panel Height

Follow the instructions given in paragraph 2.1.2, except that the container size must be no smaller than 26½ inch x 25 inch x 13½ inch.

UNHOLTZ-DICKIE CORPORATION

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